Effect of backgrounding systems on winter and finishing performance, forage intake, carcass characteristics of beef calves and economic analysis

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ABSTRACT

A 2-year winter grazing and feedlot finishing trial (Exp 1) and subsequent *in-situ* nutrient disappearance study (Exp 2) were conducted to evaluate the effects of swath grazing forage barley (*Hordeum vulgare*, cv. Ranger) or foxtail millet (*Setaria italica,* cv. Golden German) compared to grass-legume hay fed in drylot on calf performance. In trial1 in each of 2 years, 120 spring born Angus calves (60 steers, 60 heifers) were fall weaned, stratified by weight, allocated into 20-head groups then assigned randomly to one of the three replicated (n=2) backgrounding (BG) systems. Backgrounding systems were (i) swath graze barley (BR); (ii) swath graze millet (ML); and (iii) bunk fed ground hay drylot (DL). Swath grazed calves were limit fed in 8 ha paddocks with 3 d grazing periods, using electric fencing for 96 d each year. All groups received a pelleted supplement at 0.62% BW. Calves were weighed at start, every 21 d and end of background period. Following the BG period, calves were placed in feedlot, separated by sex and BG treatment and fed a similar finishing ration and harvested at a targeted endpoint of 12 mm back fat. Forage samples collected every 21 d were analyzed for DM, CP and digestible energy (DE) and change in nutritive quality over the grazing period. DE content was greatest (P<0.05) for BR (2.6 Mcal/kg) and least for DL hay (2.2 Mcal/kg). Quality of all the three forages did not change over the grazing period except for an increase (P<0.05) in NDF of millet. Calf ADG was greatest (P <0.05) for BR compared to ML or DL, while dry matter intake (DMI) of the BR calves tended to be greater (P=0.11) than ML or DL calves. No treatment differences were observed in the finishing ADG (P>0.05) and carcass characteristics (P>0.05) of calves from the three backgrounding systems. In Exp 2, four dry ruminally cannulated Holstein cows fed ground grass hay were used in an *in-situ* degradability study to determine the extent of degradation and rumen kinetic parameters of the 3 forages used in Exp 1. Effective degradability of DM and CP were similar for barley and millet and greater ($P<0.05$) than grass legume hay while NDF degradability ($P<0.05$) of millet was greater than that of barley or grass legume hay. These findings indicate that swath grazing barley or foxtail millet fed to beef calves resulted in similar or decrease performance compared to a traditional drylot pen system. Cost of gain for the barley swath grazed backgrounding system calves was 43 and 60.5% lower compared to a swath grazed millet or drylot system, respectively. The economics of these systems would indicate that backgrounding of calves on swath grazed barley is a more efficient and low cost system compared to drylot.

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Dedicated to

My Parents SH.Hoshiar Singh and Smt Sarjo Devi

For your sacrifices, support, and

motivation for education.

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LIST OF ABBREVIATIONS

ADF	Acid detergent fiber
ADG	Average daily gain
ADIN	Acid detergent insoluble nitrogen
barley	Barley swath
BW	Body weight
BR	Swathed barley backgrounding system
CP	Crude protein
d	Day
DE	Digestible energy
DEI	Digestible energy intake
DL	Drylot backgrounding system
DM	Dry matter
DMI	Dry matter intake
h	Hour
ha	hactare
hay	Grass legume hay
hd	head
HCW	Hot carcass weight
ML	Swathed millet backgrounding system
millet	Millet swath
NDF	Neutral detergent fiber
NDFI	Neutral detergent fiber intake

NDIN	Neutral detergent insoluble nitrogen

1.0 GENERAL INTRODUCTION

Backgrounding is the controlled rate of growth of beef animals to maximize frame size prior to the deposition of fat to obtain a greater carcass weight at slaughter (Perillat et al. 2003). Muscle development and skeletal size are related to carcass weight and the potential growth during backgrounding period (Tatum et al. 1988). However, the performance of beef animals depends on management strategies, feed type, breed or genetics, and also forage production and quality. Traditionally in western Canada, spring-born calves are grazed on pasture during the summer period (Karantininis et al. 1997). These calves are weaned in the fall and then moved to pens for the winter and fed stored feedstuffs (Karantininis et al. 1997). This is then followed by a feedlot finishing period until calves are ready for slaughter. In Saskatchewan, the cow-calf operation is the main enterprise for many beef cattle producers. High inputs and yardage costs involved in pen feeding can affect profit (Saskatchewan ministry of Agriculture and Food, 1998). In addition, consumer preference for lean meat compels the producer to enhance lean meat production to get the maximum benefit (Bidner et al. 1986). Lean meat is produced by minimizing the amount of fat on the beef carcass by optimizing the forage intake of calves during backgrounding (Schaake et al. 1993). Amount of lean meat production will depend on the growth of animals during the backgrounding phase. For sustained growth of the beef industry in Saskatchewan, there is a constant need to develop low cost backgrounding programs for calves. It is important that there is awareness among producers to determine which backgrounding system is economically feasible (Gould et al. 1999). Based on cost of gain, feed availability, markets and consumer preference, producers will ascertain whether calves should be backgrounded on swath grazed annual forages or fed processed forage in the feedlot. Calves will enter the feedlot at different stages of growth, some calves enter the feedlot shortly after weaning, while some calves are first backgrounded for 2 to 6 months before entering the feedlot (Klopfenstein et al. 2000). Cattle entering the feedlot will differ in age and weight as a result of different backgrounding systems which could produce differences in carcass quality (Klopfenstein et al. 2000).

For efficient backgrounding, emphasis should be placed on the proper selection of forage species based on agro-climatic growing conditions of the area. The forage should provide adequate quality and nutrient density for desired growth depending on the animal's requirements. Swath grazed annual forages are well suited to provide quality feed due to flexible seeding dates and large biomass production compared to cool season perennials and can lead to better animal performance in beef backgrounding systems (McCartney et al. 2008). Raising fall weaned calves on warm and cool season annual swathed forages may provide a low cost opportunity for retaining ownership of calves for more favorable early winter/spring markets. Swath grazing saves the cost of baling or chopping, hauling, stacking or packing, and feeding and manure removal (Aasen et al. 2004). In Saskatchewan, limited information is available on evaluating the potential of swath grazing annual forages in terms of production and their effects on backgrounding and finishing performance and carcass characteristics of calves. Therefore, it is important to investigate the effect of barley (cv. Ranger) and millet (cv. Golden German) swath grazing during backgrounding on animal growth and subsequent finishing performance and carcass characteristics of spring born calves. Furthermore, the economics of each system needs to be determined. The objective of this literature review is to provide an overview of research on the comparative analysis of backgrounding fall weaned calves on cool season (barley, oat) and warm season (millets, corn) annuals relative to traditional pen feeding of grass legume hay.

2.0 LITERATURE REVIEW

2.1 Drylot backgrounding system

Drylot backgrounding is confined feeding of beef cattle with forages, crop residues and grain which may lead to the increased market value of cattle compared to selling the cash crop (Anderson and Boyles 2007).

2.1.1 Advantages of backgrounding beef animals in drylot

Drylot backgrounding increases the economic value of crop residues, forage and grain and other feedstuffs with better monitoring of herd performance (Anderson and Boyles 2007). It is very easy to acclimatize the calves to bunk feeding . Simultaneously, it promotes the efficient use of land resources which ultimately enhances the overall beef production per unit of land compared to pasture grazing (Anderson and Boyles 2007).This system provides the opportunity for efficient use of drought stressed or moisture affected feeds (Thomas and Durham 1964). Drylot backgrounding provides nutrients in the form of manure which can accumulate during feeding of animals for the crops in the following season (Thomas and Durham 1964).

2.1.2 Disadvantages of backgrounding beef animals in drylot

Backgrounding in drylot is associated with higher cost of labor, more complicated and intensive use of equipment for feeding, high cost of manure hauling and high cost of yardage. However, there is a relatively fast depreciation of equipment and facility (Anderson and Boyles 2007). It also requires the skills of a person for balanced ration formulation and management of the herd. This increases the overall cost of production (Anderson and Boyles 2007). Risk of infectious and contagious disease transmission is always high due to mixing and exposure to a challenging environment with dust, mud and flies. Requirement of harvesting and storing feeds for growing animals increases the cost of gain (Anderson and Boyles 2007).

2.2 Alternative backgrounding systems

Beef producers in western Canada may choose to adopt swath grazing as a management practice for bred heifers, mature cows or weaned calves during winter months. Animals are allowed to graze swathed forages windrowed throughout the winter feeding period which ultimately results in decreased feeding cost, corral cleaning and machinery cost (McCartney et al. 2004). Grazing swathed forage in the winter, rather than baling, storing, and feeding, might enable a livestock producer to lower some production costs. Cool and warm season annual crops such as barley, oat, millet and corn are grown and swathed at appropriate maturity stage to facilitate easy apprehension of feed by animals during winter (McCartney 1998). Delaying the seeding of annuals will improve the quality of the forage because of reduction in time between swathing and grazing (Klein 1996; McCartney 1998). More importantly, this will limit the negative effect of weathering on forage quality and discourage formation of toxins from mold growth (McCartney et al. 2004). Recent research has indicated that late seeding of warm season annuals such as millet or corn produce more favorable biomass and can minimize the effect of weather and toxins due to swathing of crop prior to onset of a frost killing (Klein, 1999). The percentage loss of forage was higher in swath grazing (26%) compared to bale grazing (12%). However this wastage was reduced to 18% by allowing mature cows to graze the swath residue after the calves (Behling 1999; Volesky et al. 2002).

2.2.1 Advantages of swath grazing

Swath grazing can reduce the cost of gain with less yardage and manure hauling charges (Lardner 2005). It also reduces cost of haying and feeding by eliminating the requirement of bailing, hauling, and stacking. Another important saving is machinery maintenance cost because it avoids the use of baler, hauling machine and feeding equipments (Thomson 1999). It provides high quality forages to the animals throughout the winter because the crop was cut at its highest quality and then windrowed (Surber et al. 2001). Swath grazing also minimizes the harsh weathering effect on the crop (McCartney et al. 2004). During swath grazing, the cattle are not concentrated at one point. This reduces the cost of manure handling the following spring, as in the case of stockpile grazing. Swath grazing also reduces the risk of the spread of communicable disease (Surber et al. 2001).

2.2.2 Disadvantages of swath grazing

During heavy snow, crusting of the ice limits feed accessibility and requires breaking with a tractor to make the forage accessible for the livestock. This leads to an increase in the overall operation cost (Surber et al. 2001). Energy supplementation is mandatory to maintain targeted rate of gain in swath grazed livestock, particularly in extreme cold weather (Surber et al. 2001). The physical problem with swathing of some crops such as corn and sorghum-sudangrass may limit the potential use of this technique (McCartney et al. 2009). Wind may damage the windrowed forage before its grazed by livestock which can be managed by rolling the swath after cutting (Surber et al. 2001). Establishment of portable electric fences increases overall production cost .There is always a potential risk from wildlife of loss of swathed crop particularly elk and deer who prefer the ungrazed swath (Surber et al. 2001).

2.3 Annual Forages

2.3.1 Cool season annuals

2.3.1.1 Barley

Barley (*Hordeum vulgare* L.*)* can be utilized as an animal feed in many different forms such as grain, silage or green feed in different parts of world. Barley is an annual, cool season cereal belonging to *Poaceae* family and is the second most grown cereal crop in Canada.

Barley seeded in the spring is commonly used for swath grazing in Western Canada during fall or winter (May et al. 2007). Its important to choose the proper seeding date for barley because early seeded crop (May) swathed in August can lead to substantial decreases in quality due to weathering (May et al. 2007). In contrast, late seeding (June) of barley swathed in early September decreases the total biomass produced due to less growth and utilization by grazing animals (May et al. 2007; Baron et al. 2006). Compared to other annual forages like oat, wheat, and triticale, barley always produced more biomass when grown in the brown soil zone with low seeding rates in dry weather conditions (McCartney et al. 2008). Barley (cv Ranger) had higher digestibility, lower crude protein (CP) and neutral detergent fiber (NDF) than oat at the same stage of harvesting (McCartney et al. 2008). Baron et al. (2006) reported that in vitro organic matter digestibility (IVOMD) of barley swath cut at soft dough stage was 60.5% in fall which decreased to 54.4% in early spring which is similar to results reported by Aasen et al. (2004). In the same study, CP content of barley swath was 13.5 % (DM basis) initially, which declined to 12.1 % (DM basis) which is contrary to the results of Aasen et al. (2004) who reported stability in crude protein levels during winter. There was a linear increase in NDF and acid detergent fiber (ADF) concentration from 57.6% and 31.6% (DM basis) in September to 62.3% and 35% in

February respectively. Overall, feeding losses due to weathering was less compared to other studies (Volesky et al. 2002; Baron et al. 2004).

Nutritive value of barley swath is usually higher at the soft dough stage. At this stage it, supplies more energy than the maintenance requirements of gestating cows if grazed freely (Aasen et al. 2004). Mid pregnancy beef cows grazing swathed barley showed selectivity for barley heads first and left straw intact in the swath. With adverse weather as winter progresses this selective grazing could result in an energy deficiency (Baron et al. 2006). At Lacombe Alberta, cows grazing on swathed barley gained less (0.39 kg d^{-1}) compared to barley silage (0.42 kg d^{-1}) even though they consumed 21.2% more digestible energy (McCartney et al. 2004).

2.3.1.2 Oats

Oat (*Avena sativa* L.) are grown on 1.8 million hectares in Canada and 0.8 million hectares in the United States. Oat ranks in the top 5 crops in Manitoba and Saskatchewan and contributes to the largest part of total area grown in Canada (Fraser and McCartney 2004).

Research conducted at Lacombe, Alberta from 1932 to 1952 on spring cereal crops for forage production revealed that oat yield and quality was greatest compared to barley, wheat or rye with more adaptability for hay. Forage oat yield was 3640 kg DM ha^{-1} at Lacombe, Alberta (McCartney et al. 2008). Whole plant oat harvested at medium soft dough stage yielded 5520 kg DM ha^{-1} at Indian Head, Saskatchewan (McCartney et al. 2008). A study by Klein (2002) compared a cool season annual oat and the warm season annual foxtail millet (*Setaria Italica L.*) and proso - millet (*Panicum-Miliaceum L.*). The author concluded that oat was less suitable for swath grazing compared to the millets. This was due to low biomass production with late seeding of oat.

Berkenkamp and Meeres (1988) reported that on Black chernozemic and Grey-wooded luvisolic soils, oat had the highest yield around 3350 kg DM ha^{-1} and 50% more DM than barley and was more tolerant under acidic conditions. In cereal crops, with advancing maturity, IVOMD and crude protein concentration decrease, while NDF and ADF increase (Cherney and Mertens 1982). However, Aasen et al. (2004) reported that oat IVOMD, ADF and NDF and barley ADF increased while crude protein was not affected following the swathing of the crops. This was perhaps due to leaching of cell solubles with the melting of snow and rain on the swath as observed by Burns and Chamblee (2000a). Oat should be harvested in Saskatchewan at late milk or early dough stage for maximum nutritive value; later harvesting will reduce the feeding value (Christensen 1993).

2.3.2 Warm season annuals

2.3.2.1 Millet

Under typical western Canada climatic conditions, cool season cereal crops such as barley *(Hordeum vulgare L.)* or oat *(Avena sativa L.)* are used for winter feeding of beef cattle. Several studies have concluded that early seeding (May) of oat or barley increased degradation of swathed forage quality in August due to precipitation whereas late seeding in June resulted in reduced biomass production (Baron et al. 1994; Kibite et al. 2002). This problem initiated producers to evaluate the adaptability of warm season cereals such as corn or foxtail millet (*Setaria italica* L.) for swath grazing (May et al. 2007). McCaughey et al. (2002) found that swath grazing foxtail millet (cv. Golden German Millet) is feasible with good biomass production and less weathering affect on quality compared to cool season crops. High variability in yield due to changes in environmental conditions can render pearl millet, sorghum sudan grass and corn unsuitable for swath grazing in Saskatchewan (May et al. 2007). Neville et al. (2006)

did a comparison of crops in North Dakota, between a cool season perennial, crested wheat grass *(Agropyron cristatum)*, warm season perennials, big blue stem swath (*Andropodon gerardii)* and warm season annual foxtail millet swath (*Setaria italic*). Foxtail millet had the highest crude protein 9.4% (DM basis) and big bluestem had the lowest (4.2) % (DM basis) with an intermediate value of 7.8% (DM basis) for the crested wheat grass. Total biomass production of foxtail millet, crested wheat grass and big blue stem swath was 7414 kg DM/ha, 3373 kg DM/ha and 2686 kg DM/ha, respectively (Neville et al. 2006).

Munson et al. (1999) and Schleicher et al. (2001) reported increases in ADF content of the foxtail millet as the grazing season progressed from October to January. In contrast, Mackay et al. (2003) reported ADF content of 34% (DM basis) for foxtail millet (cv. Golden German Millet) which remained constant throughout the grazing period. Total tract crude protein (CP), NDF and ADF digestibility of foxtail millet reported by Neville et al. (2006) were 58.2%, 66.8% and 66.9% respectively.

2.3.2.2 Corn

Typically corn (*Zea mays* L.) is grown and harvested for either grain or silage production by livestock producers in North America. It is a tall, annual warm season crop which provides flexibility for grazing of standing plants at different times of the year (Hoorman et al. 2002). Corn (*Zea mays* L.) grazing is not common in western Canada but its potential for winter grazing of beef cows in southern prairies has been evaluated (Lardner 2000, 2002, 2003; Willms et al. 1993). Being a warm season annual, lower production existed in the past in western Canada due to cool temperatures which hampered its use as a feed (Baron et al. 2003). However, recent focus on marketing of hybrid varieties along with warmer than normal temperatures during the past few years has enhanced corn silage production and interest in grazing corn in cooler regions

(Baron et al. 2003). In corn adapted areas, better nutritional and physical characteristics of the whole plant corn or even corn residue make it suitable for winter feeding of beef cows (Baron et al. 2003). Corn residue and whole plant corn have been found to provide sufficient energy and protein for non lactating dairy cows as indicated by NRC (1996) (Gutierrez-Ornelas and Klopfenstein 1991; Willms et al. 1993). Corn plants are easily apprehensible to animals even in high depth of snow during winter due to the long stalk compared to other perennial or short stemmed annual grasses (Baron et al. 2003). However, reduced dry matter yield and loss in nutritive value of whole plant corn due to weathering is a major concern. Large variation has been observed in weathering losses and changes in digestibility depending on location, harvest date and variety of corn. In a comparative study between conventional varieties (Pioneer 39K72, Pioneer 39N03, Pioneer 39T68) and short seasoned hybrid varieties (Canamaize, Amaizing Graze) at Lacombe and Brooks in Alberta, Baron et al. (2003) reported that total biomass decreased at Lacombe and increased at Brooks from September to January when averaged over varieties. A similar trend was observed for IVOMD but NDF concentration was found to increase from September to January harvest time at both Lacombe and Brooks. A probable cause of the increase in NDF and decrease in IVOMD may have been due to leaching of cell solubles from corn stalks and leaves after exposure to frost. Lamm and Ward (1981) found similar trends in loss of nutritive value due to weather. In this study, they observed that IVOMD decreased 20% in stalks and 28% in leaves and husks and NDF decreased 18 and 15% in respective components of the corn residue. Lardner (2003) reported that there is always a risk associated with corn grazing in Saskatchewan because it requires 2150-2200 corn heat unit(CHU) for optimum biomass production, as 30 years range of CHU experienced in Lanigan Saskatchewan is 1600 to 2600 with an average of 1900 which remains below its optimum requirement affecting the growth of plant.

2.4 Nutrient Requirements of Beef Cattle

2.4.1 Energy requirements

NRC (2000) has reported that the net energy maintenance (NE_m) for an Angus calf weighing 200 kg to 350 kg ranges from 4.1 to 6.23 Mcal per day. The net energy for gain (NE_g) for a similar weight animal with an average daily gain (ADG) between 0.5 and 1.5 kg ranges from 1.27 to 1.93 Mcal per day and 4.24 to 6.45 Mcal per day. NRC (2000) reported these values were based on American (U.S.) studies where the range of temperature is high (15 to 20 ^{0}C) compared to the very low western Canadian temperature during winter (Block 1999). Several factors influence maintenance energy requirements in beef cattle. These factors are body weight, breed, sex, age, season, temperature, physiological state, and previous nutrition (NRC 2000). Typically in western Canada, a major factor affecting the energy requirement of beef calves in winter condition is temperature. Therefore the affect of temperature will be discussed in this section.

NRC, (2000) calculated the NE_m requirements of cattle which are adapted to a thermo neutral environment as per the following equation:

Equation 4.1: $$NEm = (.0007*(20 - Tp)) + 0.077 \quad Mcal/BW^{0.75}$$

Where, NEm requirement of the cattle changes by 0.0007 Mcal/BW $^{0.75}$ for each degree that previous temperature differs below 20 ^{0}C. However, beef animals exposed to a chronic cold environment will increase their basal metabolic rate, feed intake and thermal insulation in order to acclimatize (NRC 2000; Degen and Young 2002). During cold stress, maintenance requirements can increase by 28 to 38 percent (Stanton 1995). More energy is diverted to heat production in the body instead of gain or production functions. This is necessary in order to maintain the internal body temperature. As such this influences the partitioning of dietary energy for maintenance and production. To maintain this equilibrium, animals will increase their feed intake (Christopherson et al. 1993). This way more energy is released as heat which lowers the animal's lower critical temperature (LCT). Heat of fermentation is also useful during exposure to cold. Energy utilized for mastication, digestion and propulsion of feed down the alimentary canal is released as heat which is useful during exposure to cold environment (Christopherson et al. 1993). More of the dietary energy is used for heat rather than for growth and productive functions to maintain the thermal equilibrium which eventually leads to changes in energy efficiency. McCartney et al. (2004) found that 18-20 % extra energy is required for beef cows swath grazing in winter due to a higher maintenance energy requirement. This was reflected in higher feed intake of swath grazed cows compared to pen fed cows.

NRC (2000) has calculated the increase in the maintenance energy due to cold stress by calculating the surface area and difference between the lower critical temperature (LCT) of the animal and environmental temperature (EAT) by the following equation.

Equation 4.2: ME_c = SA (LCT – EAT)/IN

Where, ME_c is the increase in maintenance energy requirement due to cold stress, Mcal/day; EAT is effective ambient temperature (^{0}C) adjusted for thermal radiation; IN is the total insulation (^{0}C/Mcal/m^2/day) and SA is surface area.

Based on the value of ME_c, the increase in net energy requirement for cold environment can be summarized as follows by this equation.

$$\textbf{Equation 4.3:} \quad NE_c = k_m * ME_c/EBW^{0.75}$$

Where K_m is coefficient of maintenance energy, $EBW^{0.75}$ is empty body weight of animal (kg)

Total net energy for maintenance (NE_{mc}) for cold environment becomes

$$NE_{mc} = NE_m + NE_c$$

Because of the significant affect of energy supply on the performance of calves, it is very critical to consider this extra cost of cold on the calves. Over-estimation of the energy was addressed when the NRC equations were corrected for temperature for wintering beef cows (Koberstein et al. 2001).

2.4.2 Protein requirements

According to NRC (2000) beef cattle requirements, medium framed calves weighing 200 to 300 kg require 299 to 303g metabolizable protein (MP) day^{-1}, corresponding to maintenance through weight gain of 1.0 kg day^{-1}. However in western Canada, very low temperatures result in significant loss of energy in grazing animals. Animals maintain themselves by increasing the heat production (thermo genesis) either by using the substrate from body reserves or from dietary metabolizable energy (ME). These processes will reduce the metabolizable energy available for protein accretion in the body (Reeds and Fuller 1983). In animals which have an *ad-libitum* food supply, compensation for this energy loss will be achieved through increased feed intake in chronic cold exposure (Scott et al. 1993). To maintain temperature in the thermoneutral zone (TNZ) in cold temperatures, animals will use more of protein from the body for heat production as protein turn-over contributes around 20% for heat production in the body (Newsholme 1987). Therefore, amount of protein in the diet should be higher in cold stress animals (NRC 2000).

Scott et al. (1993) reported that in cold adapted calves, there was reduced protein synthesis in muscles and skin, due to more of the amino acids being metabolized by the body for heat production in a limit fed system. In the same study, *ad-libitum* fed calves in the same ambient temperature increased their feed intake and no change in protein degradation was observed (Scott et al. 1993).

NRC (2000) has reported that 13.5 to 14.5% protein in the diet is sufficient to meet the requirements of calves exposed to stress conditions. Cool season annual like barley seeded in May had 10 to 25% higher crude protein compared to a warm season annual corn crop and were sufficient to meet the protein requirement of the pregnant beef cows (Baron et al. 2004).

2.4.3 Mineral requirements

Calcium (Ca) requirement for maintenance of a 250 kg beef animal is 8 g per day and for a weight gain of 1.0 kg per day is 32 g per day. Calcium requirements for maintenance of 300 kg beef animal is 9 g d^{-1} and for a weight gain of 1.0 kg d^{-1} is 23 g d^{-1} (NRC 2000). Phosphorus requirements for maintenance of 300 kg beef animal is 7 g d^{-1} and for a weight gain of 1.0 kg d^{-1} is around 9 g d^{-1} (NRC 2000). True absorption of calcium in the body depends on various factors such as chemical form, calcium source, vitamin D level in the diet and interrelationship with other nutrients (NRC 2000). Age, stage of production, weight and type of animal determines the requirements of Ca and P (NRC 2000). Ca and P are required for proper bone formation, cardiac regulation, membrane stability and secretion of enzymes (NRC 2000). Specially, the major role of P is to regulate the growth and differentiation of the cell, as a component of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) and to optimize the intracellular energy utilization as a component of adenosine triphosphate (ATP), adenosine diphosphate (ADP), and adenosine monophosphate (AMP). In ruminants, phosphorus plays important role in growth and cellular metabolism of ruminal micro-organisms (NRC 2000).

2.4.4 Supplementation

Protein and energy supplemention is common for livestock producers under severe winter conditions or when feeding poor quality roughage (Kartchener 1980). Intake and digestibility of native grass hay decreased in beef cattle as a result of energy supplementation especially with corn, barley, or sorghum (Lamb and Eadie 1979; Sanson et al. 1990). This is due to a substitution effect of the energy supplement for the low quality forage resulting in no net improvement in beef cattle performance (DelCurto et al. 1990b). Performance can be enhanced with an energy supplement with limited availability of high fibre, poor quality roughage (DelCurto et al. 2000). In many studies, protein supplementation resulted in higher weight gain when forage CP level was low. This has been attributed to an increase in apparent digestibility (DelCurto et al. 2000) increased intake (DelCurto et al. 1990a; DelCurto et al. 1990b). Authors suggested that protein deprivation of microbes for microbial protein synthesis decreased the microbial population leading to lowering of fermentation and passage rate leading to reduced dry matter intake (DelCurto et al. 1990b).

Feed additives can be used as growth or efficiency promotants. Monensin and lasolacid are 2 common ionophores used in beef animal diets (Kunkle et al. 2000). These compounds exert their effects by increasing propionate production, decreasing production of methane, decreasing protein degradation and amino acid deamination and production of lactic acid (Huntington 1997). These alterations divert more of the nutrients towards the growth and production of the animal. Monensin is also found effective for the prevention of acute bovine pulmonary edema and emphysema (ABPE) (Kunkle et al. 2000). This usually occurs due to the sudden transition of particularly young animals from limit grazing to *ad-lib* lush green pasture mainly affecting lungs. These changes are exhibited due to metabolism of 3-methyle indole produced during breakdown of tryptophan in rumen (Kunkle et al. 2000). Monensin is also found to be effective against bloat in grazing animals (Branine and Galyean 1990). It also helps in the fight against coccidiosis in young calves particularly by killing the invasive stage of the pathogen (Smith et al. 1981).

2.5 Compensatory growth

Compensatory growth is known as increased growth in animals following a period of restricted nutrient intake (Bohman 1955). Usually this term is associated with recovery from nutritional inadequacy but it can be caused by other environmental factors, like plant toxins, disease, parasitic infestation and high ambient temperature and genotype of animal (Drouillard and Kuhl 1999). Increased feed intake after a period of restriction leads to increased gut fill with efficient use of metabolizable energy for body gain ultimately increasing the live weight of animals (NRC 2000). However, gut fill is influenced by various factors like seasonal changes as observed by Johnson et al. (1998) in steers grazing mixed grass prairie with low of 9 % of body weight in June to 16.5% of body weight in December. Maturity of forages was found to be directly related with ruminal gut fill in steers (Burns et al. 1994). It has been concluded in some studies that fasting heat metabolism or maintenance energy requirement decreased during periods of restricted feed intake giving advantage after *ad-libitum* feed intake in terms of increased weight gain (NRC 2000). The duration of time for which an animal shows compensatory gain after restricted feeding is not clear. Wright and Russell (1991) have reported that increased rate of protein deposition was evident from carcass composition results and was attributed to compensatory growth in their study. They found a higher proportion of protein in the carcass of restricted fed animals at the end of backgrounding, compared to the animals that had access to higher feed intake from the beginning of the trial.

Currently, in the segmented North American beef industry where animals are owned by several owners during their lifetime, the practical importance of compensatory growth has increased (Drouillard and Kuhl 1999). This leads to a benefit for one segment and a loss to the other, but the overall value of the commodity remains unchanged. In a scenario, where input costs are high, compensatory growth can benefit producers by decreasing the overall cost of production (Drouillard and Kuhl 1999).

2.6 Carcass characteristics

Body composition, nutrient metabolism and subsequent feedlot performance of beef cattle are highly influenced by the different types of backgrounding and finishing systems (Hersom et al. 2004). During the growing phase of beef animals, depending on type of diet and level of feed intake, changes in body composition occur by decreasing or increasing the maintenance energy requirement (Sainz et al. 1995). This increase in body condition during the growing period may decrease the growth rate and efficiency of animals during finishing (Mies 1992).

Hershom et al. (2004) found that steers fed a high energy diet (winter wheat forage) compared to a low or restricted energy diet (tall grass dormant native range) during backgrounding had higher initial marbling score in the finishing phase due to more body fat at the end of backgrounding. Final marbling score at the end of finishing period was similar across the treatments. These findings were similar to the study of Sainz et al. (1995) and Drouillard et al. (1991) where steers fed *ad-libitum* and restricted fed during growing phase had differences in initial marbling score but no differences at the end of finishing when steers were slaughtered at a common back fat level. In contrast, calves wintered on native range and cool season grass with ADG's of 0.21 and 0.61 kg respectively, had similar feedlot gains for both systems but low winter gaining calves had lower marbling score at the end of finishing. Cattle winter grazing on different diets with 0.19 to 0.72 kg d^{-1} gain reported no differences in carcass quality grade when adjusted to equal fat thickness at slaughter and concluded that winter gain does not affect carcass quality (Klopfenstein et al. 2000).

2.7 Measuring animal performance

2.7.1 Determination of live weight

Animal performance is the main criteria to ascertain whether nutrient requirements of an animal are fulfilled though grazing of forage (Rohr and Daenicke 1984). Change in the live body weight is an indicator of animal performance (Rohr and Daenicke 1984).

Gut fill, handling practices and time of the day are all factors resulting in variability in animal live weight. Variation in gut fill weight can be minimized by weighing the animals at the same time each day at each weigh interval. It can also be achieved by not allowing the animals to access the feed and water for 12 hours and subsequently weighing the animal to achieve shrunk body weight (SBW) (Heitschmidt 1982; Cook and Stubbendieck 1986). When environmental or management conditions do not allow the animals to go through a period of shrink, the mean of 2 consecutive weights taken at the same time over 2 days is used to reduce the variation due to gut fill (t'Mannetje 1978). Handling of animals near the weighing station may cause shrinkage of 2-3% in body weight (Barnes et al. 2007).

2.7.2 Determination of fat cover

Estimation of level of subcutaneous fat deposition is important due to its association with energy balance of the animal (Pryce et al. 2002). In a positive energy balance, fat cover will be increased whereas in an energy deprived condition, fat cover will be minimal. Due to the limitation of live weight change correlating the composition of body weight gain, use of body condition score (BCS) or ultrasound methods may be used to assess nutritional status. Use of ultrasound to estimate the carcass composition in domestic livestock stimulated the beef industry to develop a grading system to assess live animal carcass composition (Perkins et al. 1992). Such a system could help in the development of value base marketing systems by estimating the lean and fat level of the carcass with ultrasound of the live animal (Perkins et al. 1992). Ultrasonic imaging is a non destructive technique to estimate the 12th rib fat thickness and *longissimus dorsi* muscle area in live beef animals (Stouffer et al. 1961). It involves emission of electric pulses as high frequency sound waves which are converted in to images depending on the density of the tissues being examined (Houghton and Turlington 1992). Hassen et al. (1999) reported that based on the real time ultrasound data collected in the early days of finishing in the feedlot, prediction equations can be developed to predict lean weight and composition of carcass at slaughter. These equations could be used to calculate the number of days required to reach a desired weight under a given management system (Hassen et al. 1999).

Even though measuring body fat using the ultrasound technique is quite useful for the illustration of body composition, some errors still occur. Minor technical error due to incorrect measuring by the technician of back fat levels has been observed. Variability in the recording can be minimized through the proper training of technician (Hassen et al. 1999).

Body condition score (BCS) is a subjective determination of the body reserves based on the external appearance of the animal. It involves a visual physical estimation of the body fat reserve at some point on the animal's body (Edmonson et al. 1989). Initially, this system was developed for ewes where a score of 0 (very thin) to 5 (very fat) were assigned based on palpation of the backbone and lumber processes for sharpness and covering of the bone (Jefferies 1961). Later, Lowman et al. (1976) adapted this technique for beef cattle in North America with the addition of palpation of the tail head and still used to assess the nutritional status of beef and dairy animals. With this development, an 8 point system was developed in Australia and 10 point system in New Zealand, mainly for the dairy cows. Questions have been raised about the validity of the technique due to its subjective nature and variation in results recorded by different technicians over a period of time. Comparison of BCS data with quantitative measurements of ultrasound over time was carried out, to validate this system (Domecq et al. 1995). Body condition scoring is used to assess the energy status of the beef animals. Body condition score and ultrasound techniques can be used to modify the various managemental or feeding strategies by revealing the change in body condition or composition over time (Waldron et al. 2006).

2.8 Measuring forage characteristics

2.8.1 Estimation of forage yield

Measurement of forage yield will determine the production capacity of beef cattle operations. The potential of a pasture for grazing and its utilization is assessed through quantifying the forage weight, yield and its biomass (Cook and Stubbendieck 1986; t'Mannetje 1978). Different methods for estimating the forage yield are categorized as destructive and non-destructive (Cook and Stubbendieck 1986; t'Mannetje 2000).

Clipping is a destructive technique which is the most common and accurate method available. Clipping forage biomass facilitates direct and objective measurement of forage production. In the case of mixed species vegetation, clipping is highly advantageous because it enables the segregation of not only different forage species but also the live and dead components of the sward as well (Cook and Stubbendieck 1986). During the grazing period, estimation of cumulative forage yield is more beneficial as it will measure the actual forage growth for that specific period. The cage or grazing exclosure technique can be used to estimate the forage yield during the grazing period (Cook and Stubbendieck 1986). With this method, cages or exclosures are placed on a sample portion of pasture called the protected area (area not allowed for grazing). The difference between biomass weight of clipped cage samples and a similar grazed area determines the forage utilization (Cook and Stubbendieck 1986). In addition, it also gives an idea about the growth or re-growth of forages between the 2 specific clipping dates, by taking the difference between the amount of biomass inside the cage on a specific clipping date and the amount of forage outside the cage at a previous clipping date (t'Mannetje 1978). The main drawback associated with this technique is placement of cages on a pasture will become focal points for livestock, resulting in increased trampling around the cages (Popp et al. 1997) thus leading to bias in forage yield results, as well as for forage utilization (De Leeuw and Bakker.1986)

Measurement of canopy height has also been used as a non-destructive indicator of biomass production (Harmoney et al. 1997). In this method, canopy height is measured in different ways which may involve recording the measurement of the tallest plant within a defined area around a ruler or stick (Harmoney et al. 1997). Subjective variation while measuring the canopy height and disagreement over which plant or its parts should be used to estimate the mean of canopy height were the major drawbacks of this technique (Ganguli et al. 2000). To minimize these errors, measurement of canopy height with plastic disks, or a rising plate meter was developed (Ganguli et al. 2000). The relationship between leaf area index (LAI) (foliage per unit of ground area) and biomass production is linear which leads to development of canopy analyzers to measure the biomass indirectly (Harmoney et al. 1997). The cost of canopy analyzer and variability in the readings with different users however, limits its use for estimation of forage yield.

2.8.2 Estimation of forage quality

To get optimum production from grazing animals, it is very important to determine the botanical composition of the different constituents of the pasture. This may help in determination of nutrient level and formulation of the ration. In contrast to concentrate feeds, forage chemical composition can alter within plant species, physiological age of the plant, time of grazing and harvest (Adesogan et al. 2000).This is very important to collect a correct representative sample depending on the goal of the study. Even though it is very laborious and time consuming, focus should be on collection of that portion of the plant which was eaten by animal to determine the chemical composition of the diet accurately.

2.9 Estimation of intake

Accurate and precise feed intake estimation is considered an important factor in studies investigating animal production, pasture production and grazing management (Allden 1962). Today there are several techniques available for estimating forage intake of grazing animals on pasture. These methods are commonly based on the use of markers, observation of ingestive behavior, herbage mass disappearance, evaluation of forage characteristic and measuring animal performance. Estimation of intake of an individual animal can be done by markers or ingestive behavior based techniques. For the measurement of intake of groups of animals on pasture, other techniques based on the disappearance of herbage mass, prediction from forage characteristics or calculation of energy requirement based on observed animal performance are more appropriate (Macoon et al. 2003).

2.9.1 Methods for estimation of forage intake

2.9.1.1 Evaluation of animal performance

Short term feed intake rate can be determined by recording the change in body weight (BW) of the animal before and after grazing of the pasture or by pressure transducers attached under each hoof measuring the weight changes. Forage Intake (FI) can be calculated by the following equation (Gordon 1995):

$$FI= (W_a +F+U+IWL)-W_b$$

Where W_b and W_a, are the weights of the animal before and after grazing, F and U are weights of faeces and urine produced and IWL is the insensible weight loss (respiration and other obligatory weight losses measured in pen housed animals with no access to food or water, in environmentally similar condition to that of grazing animals). This method is less time consuming and gives accurate estimates of feed intake but highly sensitive and there is need for precise scales (Gordon 1995).

2.9.1.2 Herbage cutting method

For determination of pasture intake a fixed proportion of the area is measured from total forage area. The total herbage of the area is calculated before the commencement of grazing (pre-grazing). Further, residual herbage is determined post-grazing in a similar manner. The difference between the two herbage masses will give an estimate of the herbage consumed (Meijs 1981; Macoon et al. 2003). This technique has been adopted by various researchers for the estimation of the dry matter intake in many different ways.

Dry matter intake (kg/d) can be calculated by the formula:

$$\text{DMI (Kg/d)} = \frac{\text{DM inside cage (kg h}^{-1}\text{) - DM outside cage (kg h}^{-1}\text{)} \times \text{area (ha)}}{\text{Number of grazing days}}$$

This technique is very useful for the estimation of intake for a short grazing period or when large parts of the herbage mass are consumed. However, high variability in dry matter intake estimation may be due to regrowth and trampling of the forage (Undi et al. 2008).

2.9.1.3 Prediction equations for intake estimation

Intake of the forage can be estimated using prediction equations and from the performance of the grazing animal (Logan and Pigden 1969; Baker 1988). This procedure will take in to account an estimate of energy (digestible, metabolizable or net energy) needed by the animal to meet its daily performance and maintenance requirements. Minson and Macdonald (1987) developed an equation for estimation of the DMI per day based on live body weight and average daily gain of the animal grazing a particular pasture. The equation is as follows:

$$\text{DMI (kg/d)} = (1.185 + 0.00454\text{BW} - 0.0000026\text{BW}^2 + 0.315\ \text{ADG})^2$$

where BW=body weight (kg) and ADG =average daily gain (kg/d)

National Research Council (2000) has also reported an equation for DMI based on the NE_m concentration of the standing forage .The equation is as follows:

$$DMI\ (kg\ /d) = SBW^{0.75} \times (0.1493 \times NE_m - 0.046 \times NE_m^2 - 0.0196)$$

Where, $SBW^{0.75}$= shrunk metabolic body weight (Kg), NE_m= standing forage net energy for maintenance (Mcal kg^{-1} DM) and NE_m values can be derived from the ADF content of the forage (Van Soest 1979).

2.9.1.4 Estimation of digestible dry matter (DDM) by fecal output and in-vitro fermentation method

This method is one of the most widely and successfully used techniques based on digestibility estimates of consumed pasture and fecal output. Feed intake of the grazing animal can be predicted by rearranging the following equation (Dove and Mayes 1996; Lippke 2002):

$$Intake = fecal\ output\ x\ (1 - DDM)^{-1}$$

Measurement procedures for disappearance of dry matter (DDM) (Tilley and Terry 1963; Goering and VanSoest 1970) during in-vitro fermentation (IVDMD) of sward sample are also commonly used to get estimates of digestible dry matter. Samples from reference forages with known DDM should be run together with forage samples with unknown DDM, along with a correction factor for the IVDMD values of the reference forage.

2.9.1.5 Markers for estimation of feed intake

Markers are chemical entities present in the feedstuff (internal) or added to the feedstuff (external) (Kotb and Luckey 1972).

2.9.1.5.1 External markers

External markers are those entities which are added externally to the feed consumed by the animal (Romanczak 2005). Estimate of fecal output by using an external marker with constant and known recovery rate can be calculated according to the following equation (Romanczak 2005):

Fecal output = Dose of external marker x (marker concentration in feces) $^{-1}$ x recovery rate

The recovery rates of the markers can be calculated by dividing the total weight of marker excreted in feces (g) by the total weight of marker given (g).

Chromium oxide (Cr_2O_3) and ytterbium chloride ($YbCl_2$) are the two most common external markers. Cr_2O_3 is the most extensively used marker for estimation of feed intake, but it has some disadvantages associated with its administration. It has variable flow with liquid and particulate material (Ohajuruka and Palmquist 1991). There can be diurnal variation in recovery because it is a dense powder and sediment in the reticulorumen resulting in intermittent release to the lower GI tract (Kotb and Luckey 1972; Dove and Mayes 1991; Momont et al. 1994; Lippke 2002).

2.9.1.5.2 Internal markers

Internal markers are the naturally occurring entities within the plants. Commonly used markers are chromogen (Reid et al. 1949), lignin (Drennan et al. 1970), alkanes (Mayes et al. 1986) and acid insoluble ash (AIA). When an internal marker is used, DDM is determined by following equation (Romanczak 2005):

DDM = 1- (marker concentration in feed) x (marker recovery rate) x (marker concentration in feces)$^{-1}$

2.9.1.5.3 Alkanes

These are long chain saturated fatty acids (ranging from 19 to 35 carbon) present in cuticular wax of the plant and can be used as both external or internal markers to estimate feed intake and plant digestibility (Mayes et al. 1986; Ohajuruka and Palmquist 1991). Short chain alkanes are detected in lesser amounts than long chain alkanes in the feces. The most commonly used naturally occurring alkanes are nonacosane (C29), hentriacontane (C31) and tricontane (C33). Advantages are no marker preparation is required, relatively cheap and easy analysis by gas chromatography (Ordakowski et al. 2001)**.** Each plant has a different alkane profile, so it is possible to determine diet composition on the basis of fecal alkane pattern (Duncan et al. 1999)**.** Individual animal intake can be determined. The main limitation is incomplete recovery of alkanes in feces due to absorption in small intestine (Dove and Mayes 1996)

2.9.1.6 Acoustic/wireless method

Forage intake rate can be accurately computed based on bite mass information (Barrett et al. 2001). Allden (1962) has postulated herbage intake of grazing animals (I) as the product of the time spent grazing (GT), the rate of biting during grazing (RB) and the weight of herbage consumed per grazing bite (BM):

$$I = BM \times RB \times GT$$

2.10 Organic matter digestibility

Digestibility of nutrients in the rumen determines the contained energy of the feeds useful for the animal. Digestibility refers to the loss of nutrients in the feces after ingestion of the food (Kitessa et al. 1999). It can be measured using with three different methods: (i) it can be predicted based on the chemical composition of the feed; (ii) *in-vitro* and (iii) *in-situ* degradibilty. Significance of rumen degradability exists when it predicts the degree to which nutrients are available in the rumen from different feed stuffs (Nocek et al. 1988). Different types of *in-vitro* methods have been developed to estimate digestibility by simulating the digestion process in the gastrointestinal tract of the animal.

2.10.1 Prediction equation method

With this method, association (correlation or direct cause-effect) between the concentration of a chemical ingredient in a feed and *in-vivo* digestibility of the feed is used to predict digestibility (Kitessa et al. 1999). The main advantage of this method is that it is relatively rapid, fast. Complete ignorance of the biological variable affecting the digestibility is the disadvantage associated with it (Kitessa et al. 1999).

2.10.2 In-vitro digestibility determination.

To overcome the problem of variation arising due to lack of biological process in prediction method, use of *In-vitro* method is useful (Abrams 1988). Different methods have been used to measure the *in-vitro* digestibility.

2.10.2.1 Rumen liquor-pepsin method

Tilley and Terry (1963) developed a 2- stage digestion method which involves incubation of the feed sample in strained rumen liquor for 48 h followed by a second 48 h period digestion in acidified pepsin to simulate the biological process of digestion of the ruminant (Kitessa et al. 1999). This method is very accurate for the prediction of *in-vivo* DMD of most ruminant feeds except cereal straws and hay (Khazaal et al. 1995).

2.10.2.2 Enzymatic digestion method

This method involves incubation of feed samples in pepsin for 24 h followed by 48 h incubation in a prepared solution of cellulase (Kitessa et al. 1999). The advantage or practical significance of this method is its low cost, lower contamination of feed residue, non requirement of live animals, and better and fast repeatability because of uniformity of the enzyme preparation. However, the lack of interaction between the microbes and change in their behavior due to different feedstuff always results in lower digestibility of low quality feeds with the enzymatic digestion technique (Kitessa et al 1999).

2.10.3 In-situ digestibility determination

This method provides the most accurate simulation of the rumen environment in which microbes have direct contact with the suspended feed and has been used to predict the digestion in different feeding systems for long time (Nocek et al. 1988). This method involves suspension of the feed material in a porous bag in the rumen of a cannulated animal for a period of time. After incubation, microbial activity is stopped by washing with cold water (Nocek et al. 1988).

Determination of extent and rate of rumen degradation of the feed and its constituents is achieved after analysis of the feed residue remaining after incubation in the rumen for a period of time. The analysis of feed residue partitions feed material in 3 fractions based on availability in the rumen: Soluble (S), potential degradable (D) and non-degradable (U) (Nocek et al. 1988) as well as rate of disappearance of a nutrient can be determined. Based on these fractions, dry matter disappearance can be estimated with following equation.

$$P = S + D\,(1- e^{kt})$$

Where, P is DM disappearance at time t, S is rapidly degradable and D is slowly degradable fraction, k is rate of DM degradation (yu et al. 2004). Compared to the *in-vitro* incubation method, *in-situ* incubation method resulted in lower lag time, and greater rate and extent of degradation over a period of time (Varel and Kreikemeier 1995). Variations in the results are mainly due to sample size, bag porosity, weight of sample: surface area of bag, location of bag in the rumen, washing procedure, diet, and species of the animal (Kitessa et al 1999).

2.11 Economics of backgrounding programs

In the current system of forage based beef production systems, producers have developed several techniques to remain profitable in times of increased competition (Bowman and Sowell 2003). These are mainly the use of complementary forage, genetic modification of the plant, and alteration in the ruminal microbial system to enhance beef production (Bowman and Sowell 2003). When a ruminant's nutritional requirements are not met with conventional pasture especially during fall and winter, swath gazing is equally efficient as stockpile grazing in fulfilling this nutritional demand (Aasen et al. 2004). In cow calf operations in Alberta, the feeding cost associated with traditional pen feeding systems in the winter ranges from 60 to 65 % of the total cost of production (Kaliel and Kotowich 2002). Feeding cost of cows during winter was around 50-60 % per cow less on pasture compared to dry lot feeding (Willms et al. 1993). Volesky et al. (2002) reported that feeding cost of weaned calves on a bale feeding system was around 37 % higher than a windrowed perennial grass grazing system.

In the Canadian prairies, swath grazing of whole plant cereal crop is one technique used to decrease the feeding cost and extend the grazing period of beef cows during winter (Entz et al. 2002). This is achieved through reducing the cost linked with mechanical harvesting, handling, feeding and manure removal (Johnson and Wand. 1999). Swath grazing of whole plant barley costs around $70 less per cow and also 38% less labor cost compared to traditional dry lot feeding over a 100 day grazing period (McCartney et al. 2004). Kelln (2010) found that the winter feeding cost of cows swath grazing was 23 and 55% lower compared to bale grazing and dry lot feeding systems over 2 years at Lanigan, Saskatchewan. Grazing cost of whole plant barley swath to mid gestation cows was around 50% and yardage cost was 79 % less compared to bale feeding silage systems (McCartney 2004).

2.12 Summary

A high grain price along with the current economic crisis has forced the beef industry to find alternative management systems to maintain the economic sustainability of producers. These systems should provide the opportunity for producers to produce the beef with limited grain supplementation in an environmentally sustainable manner. Extended grazing of calves on high quality cereal swath rather than feeding high priced grain in the drylot pen is one option to lower the cost of production.

The hypothesis presented in the research of this manuscript is that spring-born calves managed on extended fall and winter grazing of annuals in an extensive backgrounding system will have similar or improved performance, lower cost of gain, and better carcass quality and feed efficiency as compared to a traditional drylot backgrounding system.

3.0 EFFECT OF BACKGROUNDING SYSTEM ON CATTLE PERFORMANCE, FORAGE INTAKE, FEEDLOT PERFORMANCE AND CARCASS QUALITY

3.1 Introduction

Swathing annual crops provides for a more flexible grazing period and higher grazing efficiency compared to a standing crop (Aasen et al. 2004). Swath grazing leads to a reduction in cost associated with manure hauling and provide a clean environment for animals while fulfilling the nutrient requirement of a particular class of animal (McCaughey 1997).

It has been found that cows grazing swathed oat maintained their body condition and subcutaneous fat levels similar to drylot cows on a typical winter ration of hay, straw and barley grain (AAFRD 1998). Aasen et al. (2004) found that swath grazing of barley provided sufficient protein and energy required for cows in mid pregnancy through to lactation especially during fall and early winter. These authors also reported very low deterioration in forage quality as the grazing period progressed through the winter. May et al. (2007) reported that warm season annual grasses have been evaluated for hay and silage in western Canada since 1902, but advancement in the novel grazing techniques like swath grazing have lead to the discovery of new cultivars of the warm season annual cereals and their potential for winter grazing.

McCaughey et al. (2002) reported that pilot studies conducted with swath gazing of millet (*Setaria-italica)* resulted in production of large amounts of biomass and animals were able to easily access the feed through the snow. In a comparative study of foxtail millet with barley, corn, Sudan grass and oat, May et al. (2007) showed that foxtail millet (*cv. Golden German*) produced biomass similar to oat and barley under cooler temperatures. With increases in temperature yields of foxtail millet (*cv. Golden German*) were much higher than barley and oat with the millet having crude protein (CP) content of 9.7% which is sufficient for meeting the requirements of second and third trimester pregnant beef cows.

Considerable diversity exists in plant species in different forage producing areas depending on the soil fertility, annual precipitation and other environmental variables. To exploit this variation, various management techniques have been developed for the grazing animals such as rotational grazing, supplementation and intensive stocking management (Drouillard and Kuhl 1999). Consequently, it has been found that different feeding systems (which may include native range, crop residue, annual cereals or cool and warm season grasses), adopted for growth of weaned animals, have influenced feedlot performance and carcass characteristics (Capitan et al. 2004). For example limited growth during the winter of the weaned animal might allow for body weight gain to be put on during subsequent phases more economically (Baker 1975). Following the extension of the grazing period with restricted growth, compensatory growth may occur when animals are fed a high grain diet for finishing. This results in enhanced rate and efficiency of gain (Capitan et al. 2004). Various experiments have been conducted for comparing the performance and carcass characteristics of animals reared extensively relative to those raised intensively on finishing diets after weaning (Klopfenstein et al. 1999). However, limited information is available regarding the effect of extending the winter grazing period for beef calves with swathed cool and warm season annuals on their back grounding performance. In addition no information is available on the subsequent effect of winter grazing on feedlot performance and carcass characteristics. Therefore, this study was conducted with the following objectives 1) to compare the performance of fall weaned calves backgrounded on swathed forage barley (cv. Ranger), versus those raised on swathed foxtail millet (cv. Golden German) grass-legume hay fed in a traditional dry lot system 2) to compare forage quality and animal feed intake of cattle fed different annual forages throughout the grazing season 3) to evaluate and compare the feedlot performance and carcass characteristics of cattle reared under these 3 systems.

3.2 Material and Methods

3.2.1 Study site

A backgrounding trial over 2 years was conducted at the Western Beef Development Center (WBDC) Termuende Research Ranch located at Lanigan, Saskatchewan, Canada. This area is located (Longitude: Latitude) (51^0 51N 105 02' W) in the east central area of the province on the Saskatchewan Plain. The soil consists primarily of a mixture of Oxbow Orthic Black and carbonated Oxbow with a loam texture. The feedlot finishing trial was conducted after conclusion of backgrounding trials at the University of Saskatchewan Beef Research Unit located in Saskatoon, Saskatchewan.

3.2.2 Backgrounding Systems

The three backgrounding (BG) systems were (i) calves grazing swathed whole plant forage barley (BR); (ii) calves grazing swathed whole plant millet (ML); and (iii) calves bunk fed grass legume hay in drylot (DL) pens. In the first year of the study (2007-08) 8 ha of forage barley (cv. Ranger) and foxtail millet (cv. Golden German) were seeded on 12 June 2007 at 109 kg per ha and 17 kg per ha respectively with nitrogen fertilizer at 22.7 kg per hectare. In the second year (2008-09) both crops were seeded on 29 May 2008 at the same seeding and fertilizer application rate. The field was then further sub-divided into two, 4-ha paddocks to make the two replicates (n=2) for both swath grazing systems using portable electric fence. In the first year of the study

(2007-08), the barley crop was swathed at soft dough stage on 1 September 2007 and millet was swathed at 30% heading stage on 4 September 2007. In the second year (2008-09), the barley was swathed at soft dough stage on 12 August 2008 and millet was swathed on 13 September 2008 at the 30% heading stage. High tensile electric fencing was used to define the perimeter of each paddock. Animal access to feed was controlled using portable electric fence and feed was allocated on a 3-day feeding period to minimize feed wastage. Portable wind breaks (10 X 6 m) and a water trough were provided in each paddock. Bedding was also provided in each of the paddocks and drylot pens during the grazing period.

The drylot pen system was located at the Termuende Research Ranch located 0.5 km away from field site. Two drylot pens surrounded by wooden slated fences with 20% porosity fencing were used with a stocking density of 20 calves per pen. Drylot calves were fed processed (coarsely chopped) grass-legume (Brome-alfalfa) hay in bunks.

3.2.3 Experimental animals

Each year, 120 spring born and fall weaned black Angus calves (60 steers; 60 heifers) obtained from the WBDC herd were used for the study. Prior to trial start, all calves were implanted with RALGRO® (36 mg Zeranol; Schering-Plough corp, Kemworth, NJ, USA) vaccinated with Covexin® -8 (8-way modified live *clostridial* vaccine; Schering- Plough Animal Health Canada Inc.) and STARVAC™ 4 plus (a modified live BVD, PI3, IBR, BRSV vaccine; Novartis Animal Health Canada Inc.) and given 30 ml of Megamectin (Ivermectin; Novartis Animal Health Canada Inc.). The average weight of calves at the start of test was 233kg in 2007-08 and 221kg in 2008-09. Calves were adapted for 15 d to the field crop treatments prior to their allocation to the different backgrounding systems. All calves were randomly allocated to 1 of the 3 backgrounding systems.

Each replicate group (n=20) of calves (10 steers; 10 heifers) were confined in the 4 ha paddock and managed using electric fence to control access to feed. All animals were cared for in accordance with the guidelines of the Canadian Council on Animal Care (1993).

3.2.4 Crop yield estimation

Forage yield was estimated in the fall of each year prior to the start of the grazing trial. Two methods were used to estimate forge yield. In the first technique, forage biomass was measured directly in standing crop before swathing using 0.25 m^2 quadrat samples (n=15) within each replicate paddock. The second technique involved direct determination of available feed weight in each field system by randomly weighing 25 sections of swath (3 x 1 m) (8 in east side, 9 in middle, 8 in west side) in each replicate paddock. Feed was placed on a tarp, weighed and placed back in the swath. Techniques to determine the forage weight per m were described by Volesky et al. (2002).

3.2.5 Laboratory analysis

Five grab samples from the ungrazed barley and millet swath and 5 grab samples of hay from each pen of the DL backgrounding system were collected prior to start of test (SOT) and every 21d throughout the grazing trial to determine changes in feed quality. Samples from each replicate paddock or pen were composited for each sampling date for laboratory analysis. All forage samples were placed in a forced air oven at 55°C for 72 h to obtain DM content. Samples were then ground to pass through a 1 mm screen using a Wiley mill.

To predict the energy and protein content in the ration prior to start of grazing and during the trial, all forage samples collected before SOT and during the trial were sent to Norwest Labs, Lethbridge, Alberta, Canada for quality analysis. Analyses included moisture (AOAC, method

935.29), neutral detergent fibre (NDF) (FAP, method 5.1) and acid detergent fibre (ADF) (AOAC, method 973.18). Crude protein (CP) was determined by the Leco method (AOAC method 990.03).

All forage and pellet samples collected were composited by treatment for each 21 d collection period in each year of the study. These samples were analyzed in duplicate at the Department of Animal and Poultry Science laboratory. Analysis included moisture (method 930.15; AOAC 2000), ether extract (EE) (method 920.39; AOAC 2000), ADF (method 973.18; AOAC 2000) and acid detergent lignin (ADL) (method 973.18; AOAC 2000). Neutral detergent fibre (NDF) and acid detergent fiber were analyzed using an ANKOM 2000 Fiber Analyzer (ANKOM Technology, Fairport, NY). Crude protein (CP) was determined by the Kjeldahl nitrogen method (method 976.05; AOAC 2000) using a Kjeltec 2400 auto analyzer. The Kjeltec 2400 auto analyzer was also used to determine acid (ADFIP) and neutral detergent fibre insoluble protein (NDFIP) (method 984.18; AOAC 2000) with residues recovered on Whatman No. 54 paper. Calcium (Ca) and Phosphorus (P) were analyzed after ashing for 5 h at 500°C using atomic absorption and UV visible spectrophotometer, respectively (AOAC 2000).

3.2.6 Dietary energy predictions

Prior to grazing and during the trial, digestible energy (DE) of forages and supplemented pellets was determined using the grass - legume and cereal grain Penn State equations based on ADF as described by Adams (1995). The equations are as follows.

Equation 3.1 Grass- legume:

Digestible energy (DE) (Mcal kg^{-1}) = $0.04409 \times (4.898 + [1.044 - \{0.0119 \times \text{ADF}\}] \times 89.796$

Equation 3.2 Cereal grains:

Digestible energy (DE) (Mcal kg^{-1}) = 0.04409 × (4.898 + [0.9265 – {0.00793 × ADF}] × 89.796

Dietary energy (digestible energy) was calculated based on Weiss et al. (1992), where percent total digestible nutrients (TDN) was calculated with the following equation.

Equation 3.3:

$$TDN= \{0.98*(1000-\{(NDF*10)-(CP*NDFIP/10)+[0.7*(CP*ADFIP/10)]\}-(CP*10)-(ash*10)+[0.7*(CP*ADFIP/10)]-(EE*10))+[-0.0012*(CP*ADFIP/10)]^2*(CP*10)+2.25*[(EE*10)-10]+0.75*(\{(ADL*10)-(CP*NDFIP/10)+[0.7*(CP*ADFIP/10)]\}-(ADL*NDF/10))*[1-((ADL*NDF/10)/\{(NDF*10)-(CP*NDFIP/10) + [0.7* (CP*ADFIP/10)]\}) \wedge (0.667)]-70\}/10$$

3.2.7 Grazing animal management

Rations for the calves were formulated using CowBytes® software according to National Research Council (2000) with a targeted weight gain of 0.8 kg per day. Allocation of the feed was based on nutrient requirements of the animal and nutrient density of the forage in each system. Feed was allocated *ad-libitum* every 3 days by moving the electric fence. Supplement pellets (Appendix Table A.3) containing monensin sodium were provided daily at 8 am throughout the trial along with a 2:1 vitamin-mineral supplement. Grazing commenced on 19 October 2007 and 15 October 2008. Calves were removed from the paddocks on 24 January 2008 and 15 January in 2009. Total grazing days were 98 in 2007 and 93 in 2008 respectively. Following grazing and conclusion of the backgrounding trial, calves from all treatments were managed at the Termuende Research Ranch from 25 January to 25 February in 2008 and 16

January to 11 March in 2009 prior to the beginning of the finishing trial. All calves were bunk fed a similar ration of processed grass legume hay and supplemental pellet containing monensin sodium @ 33 mg kg^{-1}(DM basis) in the drylot during this transition period.

3.2.8 Determination of animal performance

Animal performance was determined by measuring the change in live BW of the animal. Body weights were taken on 2 consecutive days at the start and end of test and every 21 d throughout the trial. Supplement and vitamin-mineral feeding and access to water were prevented the morning of each weigh day and animals were weighed in the morning to control variability due to gut fill.

3.2.9 Estimated apparent animal intake

Estimated apparent dry matter intake (DMI) of calves grazing swathed barley or swathed millet was determined with the technique reported by Volesky et al. (2002). In the fall of each year just after swathing and prior to grazing, swathed forage was weighed from 10 (3m × 1m) random sections of swath to calculate feed DM per linear m of swath in each paddock. In a similar way, DM of the residual feed per linear m was estimated the following spring of each year. For determination of dry matter of residue, weight of the original crop was considered after excluding the weight of manure and any foreign material such as weeds. Feed was allocated as a fixed length of swath for each 3 d interval depending on the nutrient density of the crop and nutrient requirement of the calves for 0.8 kg per d gain according to National Research Council (2000).

Apparent intake of the animals was estimated by subtracting the residual feed from the allocated feed on 3 d basis as described by Kelln et al. (2010) with the following equation:

Equation 3.4: (kg DM allocated – kg DM residual)/n/p

Where n = 20 calves per replicate p = 3 d feeding period

All estimates were determined on a DM basis.

For the drylot calves, feed intake was calculated after measuring the allocated feed with the help of mixer wagon scale daily. Refused feed was measured weekly by weighing the orts present in the feed bunks. For estimation of intake, proportion of the grass-legume hay and supplemented pellets in the refused feed was considered to be the same as the allocated feed. For the calculation of the DMI of calves, total DM in the ration was considered from the forage and range pellets. The contribution of the 2:1 vitamin –mineral mixture (Appendix A.2) was not included due to the small amount fed.

3.2.10 Environmental data

Daily minimum and maximum temperatures were obtained from Agriculture and Agri-Food Canada as well as daily precipitation data for the Lanigan area was obtained from Environment Canada for both years of the study (2007-08 and 2008-09) (Appendix A.1). Data was then averaged in order to obtain mean monthly temperature and precipitation.

3.3 Finishing trial

3.3.1 Management & data collection

Following the back grounding trial, all calves were shipped to University of Saskatchewan Beef Research Unit for finishing. All calves were weighed for 2 consecutive days at the start and end of trial and every 30 d throughout the trial. Calves were vaccinated against Clostridial diseases with Covexin 8® (Schering- Plough Animal Health, Kirkland, Quebec, Canada), *Pasteurella* *haemolytica* and *Histophilus somni* with Somnu-star Ph® (Novartis, Mississauga, Ontario , Canada) and IBR, BVD (Type1 and 2), Parainfluenza type 3 virus and BVSV with Biostar, starvac 4 Plus® (Novartis, Mississauga, Ontario, Canada). Calves were also implanted at the beginning of trial with a TBA- Estradiol combination implant (Synovax Choice®) (Wyeth Animal Health, Guelph, Ontario, Canada).

At the feedlot, all calves were sorted by sex and backgrounding treatment and randomly assigned to 1 of 12 pens with a stocking density of 10 animals (steers or heifers) per pen in a completely randomized design. Each pen was considered an experimental unit. Calves were then adapted to a common finishing ration with a targeted end point of 12 mm back fat at which time calves were sent for slaughter.

Calves were fed *ad-libitum* twice daily at 0800 and 1400. Every 2 weeks feed, bunks were cleaned and orts were weighed to determine the feed intake per day for each pen. Individual ingredient samples were collected every 2 weeks and frozen for further chemical analysis. Subcutaneous fat depth and *longissimius dorsi* area of the live animal were measured every 2 weeks with ultrasound as described by Bergen et al. (1997). An Aloka 500 V real time ultrasound machine fitted with a 17 cm linear array transducer (Aloka 500, corometrics medical systems, Wallingford. (CT) was used. In year 1, animals were slaughtered at XL Beef Inc. Moose Jaw, Saskatchewan after reaching (the end point of) 12 mm subcutaneous fat. Hot carcass weight, quality grade, yield grade, *longissimus- dorsi* area, marbling score data was collected by Canadian Beef Grading Agency graders. Due to the closure of the XL Beef Inc. slaughter plant at Moose Jaw, Saskatchewan, in November 2008, second year carcass data of the study could not be obtained.

3.3.2 Finishing diet composition

Calves were adapted to the finishing diet through a series of eight ration changes which included a gradual increase in barley grain in the diet through replacement of barley straw and grass hay. A similar ration was given to all calves at different phases of the step up program with the final finishing ration consisting of 87.07% barley grain, 5.25% supplement and 7.68% barley silage (DM basis) (Appendix A.4) and was formulated to 1.85 and 1.21 Mcal kg^{-1} NEm and NEg, respectively (Zinn et al. 2002).

The finishing phase was designed to allow maximum gain through to the selected end point. Rations were formulated to meet the NRC (2000) requirement with the range of calcium to phosphorus ratio of 1.5:1 to 2:1. Diets also contained 27 mg kg^{-1} of monensin sodium (DM basis) (Elanco Animal Health, Guelph, Ontario, Canada)

3.3.3 Chemical analysis

Barley grain and silage samples included in the finishing ration from both years of the study were dried in a forced air oven at 55 ^{0}C for 48 hours. Silage samples were ground using a hammer mill with a 1 mm screen (Christie- Norris Laboratory mill, Christie –Norris Ltd., Chelmsford, UK) while grain samples were ground using a Retch ZM – 1 grinder (Haan, Germany) with 1 mm screen. All samples were analyzed according to AOAC (2000) by Cumberland Valley Analytical Services (CVAS, Hagerstown, MD). Samples were analyzed for DM (method no. 930.15 AOAC 2000), CP (method no.990.3 AOAC 2000) with a Leco FP- 528 Nitrogen combustion Analyzer, acid detergent fiber (ADF) (method no.973.18 AOAC 2000) and NDF was analyzed using method of Van Soest et al. (1991).

3.4 Statistical analysis

Proc Mixed Model procedure of SAS 2003 version 9.2; (SAS Institute Inc., Cary, NC) was used for statistical. One way analysis of variance (ANOVA) was used.

The experimental model was:

$$Y_{ab} = \mu + \rho_a + \alpha_b + e_{ab}$$

Where a is the block (year), b is the treatment (BG systems) , μ is the overall mean , ρ_a is the random effect to the ith year , α_b is the fixed effect of the jth treatment, and e_{ab} is the error term .

Performance data including average daily gain (ADG), body weight change (BWC), dry matter intake (DMI) and digestible energy intake (DEI) were analyzed using a Randomized Complete Block design (RCBD) with year as a block. Swathed barley (BR), swathed millet (ML) and grass-legume hay in the drylot (DL) were included as main treatments with 4 replicates per treatment over 2 years. Each replicate group of calves (n=20) was considered an experimental unit for a total of 12 experimental units over the 2 year study. Forage data (change in quality) was regressed against grazing days after swathing with sampling time as a fixed effect and year as a block. For the finishing trial, animal performance results were analyzed as a RCBD with pen as experimental unit. The model included fixed effect of backgrounding treatment, sex, backgrounding treatment × sex with year as a blocking factor. As expected the effect of sex was significant, however, interaction effect of treatment × sex was not significant ($P>0.05$) and hence, sex and backgrounding treatment × sex interaction were removed from the model and, data were re-analyzed to assess only the main effect of backgrounding treatment. Carcass data (one year) was analyzed using a completely randomized design (CRD). Marbling score data were analyzed using the GLIMMIX macro (SAS, Version 9.2; SAS Institute, Inc. Cary, N.C. USA) with a binomial error structure and logit data transformation. Results are discussed as significant if $P \leq 0.05$ and as a trend if $P > 0.05$ and $P \leq 0.10$. Least square means were used to separate treatments means.

3.5 Results and Discussion

Fluctuations in the weather patterns during the growing season particularly from June to September over the 2 respective years (2007 and 2008) of the study affected the production of the crops as reflected by variation in yield of pre-swath standing barley (8067 kg ha^{-1} in 2007 vs 8707 kg ha^{-1} in 2008) and millet (9077 kg ha^{-1} in 2007 vs 6321 kg ha^{-1} in 2008) (Table 3.1). Total rainfall in June was 34% and 13% less than the 30 year average rainfall in 2007 and 2008 respectively (Environment Canada , Appendix A.1). July precipitation was 58% less in 2007 and 24% higher in 2008 compared to the 30 year average precipitation. High variation was also observed in the ambient temperature during the growing season over the 2 years of the study. In 2007, June temperature was 4.2 ^{0}C lower and July temperature was around 5 ^{0}C higher than the 30 year average temperature. In 2008, August temperature was 3 ^{0}C higher otherwise normal temperatures were observed compared to the 30 years average over the rest of the growing season. Variability in precipitation and temperature existed during the fall and winter grazing period as well. October precipitation was 58% lower and 67% higher than average in 2007 and 2008 respectively, whereas November precipitation in 2007 was 3 times higher than the 30 year average.

3.5.1 Forage yield and quality

Rations for the calves in BR and ML backgrounding systems included *ad-liblitum* access to swathed barley or millet whereas in the DL system, the grass legume hay was provided *ad-libitum* targeting 5-10% orts. In addition to forages, a 13% CP beef rumensin range pellet (Appendix A.3) and 2:1vitamin-mineral mixture (Appendix A.2) (0.05 kg $hd^{-1}d^{-1}$as fed) was fed to all calves in the different backgrounding systems in both years of study. For the BR backgrounding system, swathed barley yield averaged 5625 kg DM ha^{-1} (5091 kg DM ha^{-1} in 2007 and 6159 kg DM ha^{-1} in 2008), whereas swathed millet yield averaged 3568 kg DM ha^{-1} (3955 kg DM ha^{-1} in 2007 and 3182 kg DM ha^{-1} in 2008) (Table 3.1) over 2 years of the study. Lower temperatures during the growing season in 2008 may have reduced the growth of the warm season crop (millet) while higher temperatures result in decreased growth of cool season crops (Baron et al. 2006). Klein (2008) reported that optimum growing temperature for cool season crops like barley is 18 – 24 ^{0}C and for a warm season crop such as millet is 32 -35 ^{0}C in Saskatchewan. On average the higher yield of barley in this study was due to favorable temperatures for growth which existed during the growing period (May to September) as indicated by the climate data where temperatures in the growing season were in the range for optimum growth of barley, particularly in July and August (Environment Canada , Appendix A.1). The ration of the BR calves consisted of swathed barley with a nutrient composition of 11.9% crude protein (CP) and 58.4 % total digestible nutrients (TDN) plus supplemented range pellets fed at an average of 2.29 kg hd^{-1} d^{-1}. The feed for the ML calves consisted of swathed millet with nutrient composition of 13.60 % CP, and 52.30 TDN (DM basis) plus supplemental range pellets fed at an average of 2.33 kg $hd^{-1}d^{-1}$.

Table 3.1. Average yield and chemical composition of barley swath, millet swath and grass-legume hay and estimated ration composition and chemical analysis fed in backgrounding systems during two years

Item[Z]	Barley	Millet	Hay
Standing crop yield (kg ha^{-1})	8387	7699	-
Swath crop yield (DM kg ha^{-1})	5625	3568	-
Estimated forage composition	…………………...	% (DM basis)…………………	
Dry matter (%)	74.8	60.5	84.0
Total digestible nutrients	58.4	52.3	50.6
Crude protein	11.9 ± 0.63	13.6 ± 0.83	8.1 ± 0.91
Neutral detergent fiber	56.9 ± 2.81	64.9 ± 1.83	72.9 ± 5.03
Acid detergent fiber	35.8 ± 1.80	41.0± 2.69	48.4± 2.54
Calcium	0.33± 0.06	0.51± 0.16	0.39 ± 0.06
Phosphorus	0.29 ± 0.11	0.24± 0.05	0.16 ± 0.04
Digestible energy (Mcal kg^{-1})	2.59± 0.07	2.35± 0.12	2.23 ± 0.0
Estimated ration composition			
Barley swath	74	-	-
Millet swath	-	66	-
Grass-legume hay	-	-	70.4
Supplement	26	34	29.6
Estimated chemical analysis			
Crude protein	12.7	14.0	10.3
Neutral detergent fiber	44.9	47.2	54.2
Acid detergent fiber	29.8	31.6	37.4
Calcium	0.4	0.6	0.5
Phosphorus	0.4	0.4	0.3

[z]DM=dry matter; CP=crude protein; TDN=total digestible nutrients ; NDF= neutral detergent fiber ADF= acid detergent fiber; Ca=calcium; P=phosphorous; DE=digestible energy and (calculated using Weiss equation); BR= calves grazing swathed barley; ML= calves grazing swathed millet; DL= calves grazing hay

For the DL calves, grass-legume hay was provided as forage with a nutrient composition of 8.1 % CP, and 50.6% TDN (DM basis) (Table 3.1) with supplemented range pellets fed at 2.29 kg $hd^{-1}d^{-1}$. Predicted DE using the equation (Weiss et al. 1992) was 2.59, 2.35 and 2.23 Mcal/kg for the swath grazed forage barley, swath grazed forage millet and grass legume hay, respectively (Table 3.1). The composition of range pellets consisted of 88.4% dry matter, 15.7% CP, 10.1% NDF and 77.8 % TDN with predicted DE of 3.58 Mcal /kg (Appendix A.2).

The NDF and ADF levels of the barley swath utilized in the current 2 year study was 56.9% and 35.7% respectively. The ADF content of the barley swath was similar 34.5% to that reported by Aasen et al (2004), however CP (13.1%) and NDF (63.3%) levels were higher than values in the current study. Baron et al. (2006) reported CP concentration of barley swath was 12.0 %, similar to the current study while ADF content was lower (33.2%) and NDF content (60.8) slightly higher over 4 years of study. Chemical composition of the Golden German millet swath in this two year study averaged CP=13.6%, NDF= 64.9%, ADF= 41.0%. Mackay et al. (2003) reported CP (13.7 %) and NDF content (64.5%) of windrowed millet similar to this study while ADF content (33.1%) was lower over a period of 1 year. May et al. (2007) tried to explain the variation in forage quality of various cultivars of oat, corn, sorghum, barley, and millet grown at different sites in Saskatchewan. They found that variation in NDF and ADF content was unaffected by seeding date and harvesting time, however NDF and ADF of Ranger barley increased as the harvesting was delayed but no such trend was observed for warm season crops such as corn or millet.

3.5.2 Changes in the nutritive value of forage

Evaluation of the change in nutritive value of barley and millet swaths and grass-legume hay fed in the drylot was conducted for the grazing period (October to January). Crude protein (CP), NDF and ADF variables were considered to reflect the nutritive value of the forages. Year to year variation was not determined because of expected differences in nutritive value of the swathed forages due to difference in the weather patterns over 2 years. For the barley swath, nutritive value was not affected by sampling time (month) for any of the parameters (CP, NDF, and ADF) (Table 3.2). Baron et al. (2006) also observed a similar pattern for ADF in barley swath but for crude protein, a linear decrease was observed as the grazing period progressed from September to February. They also reported a tendency for barley NDF to increase in swath with advancement in grazing period. Aasen et al. (2004) observed stability in CP content of swathed barley and oat over winter, supporting the results of the current study. In contrast, a significant increase in NDF and slight increase in ADF of swathed barley were reported during winter in the same study (Aasen et al. 2004). As noted (Table 3.2) analysis of samples indicated that no weathering effect was found on level of CP or ADF but a linear increase (P=0.04) in the NDF content was observed for swathed millet during the winter. Contrary to relatively consistent ADF found in this study, some other studies (Munson 1998; Schleicher et al. 2001) reported an increase in ADF in swathed millet during the winter. MacKay et al. (2003) reported similar trends in ADF and NDF as found in this study but reported a cubic increase in CP content of the swathed millet. Increase in the NDF content of swathed millet as the grazing season progressed in this study is similar to the results of Lux et al. (1999) with cattle grazing windrowed hay. As expected, for the grass legume hay fed in the drylot, no change in the nutritive quality was observed because it was not exposed to weather. Overall, no significant trend in nutritive quality was observed either for the swathed forages (barley or millet) or in the grass legume hay.

Table 3.2. Change in the nutritive value (CP, NDF, ADF) of forages sampled on different dates during backgrounding trial

	Barley			Millet			Hay		
Sample time	CP	NDF	ADF	CP	NDF	ADF	CP	NDF	ADF
October 15	11.4	60.9	37.7	14.3	63.6	39.2	8.2	73.2	47.9
November 6	12.2	54.3	34.7	13.9	63.2	38.8	8.0	72.1	48.9
November 23	11.8	57.2	35.6	13.6	65.2	39.5	8.0	72.0	48.9
December16	12.1	55.8	35.6	13.2	66.1	42.1	7.8	72.1	48.8
January 8	12.4	55.3	35.2	12.8	66.7	43.5	8.1	72.6	49.5
SEM[y]	0.47	1.95	1.36	0.59	1.10	2.07	0.91	4.02	2.31
P value	0.36	0.38	0.62	0.79	0.70	0.71	0.96	0.93	0.89

[y]SEM is pooled standard error of mean

a-b Means in rows with different letters differ significantly ($P<0.05$)

The sustained quality of forages in the windrows in this experiment is likely a result of minimal weathering (i.e. low precipitation) during the study. Schleicher et al. (2001) also reported that low precipitation during the winter might not affect the quality of windrowed forage. Klein (2009) reported that millet (cv Golden German) resists weathering due to a waxy leaf surface.

3.5.3 Apparent dry matter intake

Grazing commenced on 20 October 2007 and 15 October 2008 and calves were removed from the paddocks on 18 January 2008 and 15 January 2009. During first year (2007-08) of the study, total snow depth was 63 mm but in the second year of study (2008-09) starting from November till January snow depth was 45.7 mm (Environment Canada, Appendix A.1). Freezing rain and drifting snow may have limited the accessibility of the swath for grazing by calves. This may have affected the DM intake, subsequently leading to poorer performance of calves in extensive (swath grazed) backgrounding systems compared to the intensive (drylot) backgrounding system. Similar observations were reported by Kelln et al. (2010) where high snow and low temperature during the grazing period restricted the accessibility of feed by animals in extensive systems (swath grazing and straw chaff grazing) compared to the intensive drylot calves. In Alberta, Baron et al. (2006) also reported 33 % variation in the DMI of swath grazed cows due to the differences in feed quality and accessibility to the feed due to inclement weather.

Dry matter intake (DMI) of BR calves tended to be higher (8.1 kg $h^{-1}d^{-1}$, P = 0.11) compared to ML and DL calves which had DMI of 6.2 and 7.1 kg $h^{-1}d^{-1}$, respectively (Table 3.3). In contrast, McCartney et al. (2004) found that DMI was the same for cows on barley swath compared to silage fed cows. Kelln et al. (2010) reported similar DMI (10.30 kg d^{-1}vs 11.64 kg

d^{-1} in 2005-06 and 13.34 kg $d^{-1}$and 14.34 kg d^{-1} in 2006-07) of cows in barley swath grazing system and the intensive (drylot) system in a 2 year study. Volesky et al. (2002) also observed similar DMI of windrow grazing calves and baled fed calves in Nebraska, USA. Based on outcome of these studies, and in comparison to current study, it is theorized that differences in the grazing behavior of the calves compared to cows based on preference and selectivity for the particular forage in the ration determines the efficiency of the extensive grazing system. There is a need to understand this selection process before adopting these type of backgrounding systems.

Environment and diet are two major factors affecting feed intake, provided you are dealing with the same age, breed and physiological condition of the animals (NRC 2000). Neutral detergent fiber is the predictor of the rumen fill and energy content of the diet. Dry matter intake is negatively correlated with NDF when intake is limited by fill and positively correlated when intake is limited by energy (Allen 2000). To explain the differences in DMI of calves in the current study, based on forage and supplement digestible energy content and their respective contribution in dry matter intake of animals, the digestible energy intake (DEI) was determined, and tended (P=0.13) to be highest for the BR calves (22.9 Mcal $hd^{-1}d^{-1}$) and lowest for the ML calves (16.8 Mcal $hd^{-1}d^{-1}$) and intermediate for the DL calves (18.7 Mcal $hd^{-1}d^{-1}$) (Table 3.3). Neutral detergent fiber intakes (3.5kg $hd^{-1}d^{-1}$ for BR; 2.8 kg $hd^{-1}d^{-1}$ for ML and 3.8 kg $hd^{-1}d^{-1}$ for DL) were also determined to explain the observed differences in DMI of calves. Unexpected results were found for the ML calves based on the NDF content of the swathed millet forage (Table 3.3) with no differences in (P=0.17) NDF intake among the treatments suggesting NDF intake was not affecting forage intake of ML calves. Metabolism of different nutrients produce the energy in ruminants in the form of volatile fatty acids which may limit the DM intakes based on quality of the ration (Allen 2000).

Table 3.3. Effect of backgrounding systems on calf body weight change and dry matter digestible energy, crude protein, and neutral detergent fiber intake

Item[y]	Treatment [z] BR	ML	DL	SEM [x]	P- value
BWC (kg)	79.7a	57.5b	74.8a	2.85	<0.01
DMI (kg $hd^{-1}d^{-1}$)	8.1	6.2	7.1	0.54	0.11
DE intake (Mcal $hd^{-1}d^{-1}$)	22.9	16.8	18.7	1.53	0.13
CP intake (kg $h^{-1}d^{-1}$)	1.1	0.96	0.81	0.05	0.31
NDF intake (kg $h^{-1}d^{-1}$)	3.5	2.8	3.8	0.40	0.17

[Z]BR =Calves grazing swathed barley; ML = calves grazing swathed millet; DL = calves bunk fed in drylot pens

[Y]BWC= body weight change; DMI= dry matter intake (Forage +supplement); DE intake = digestible energy intake (Forage +supplement); CP intake = crude protein intake (Forage +supplement); NDF intake =neutral detergent fiber intake (Forage +supplement)

[X]SEM= pooled standard error of mean

a-b Means in rows with different letters differ significantly (P<0.05)

Based on digestible energy intake, anticipated DMI of BR calves suggest that some other factors might have been responsible for difference in DM intake. The reason for the lower DMI intakes of the ML calves compared to the BL calves may be due to presence of the bristles (subjective observation) in the head of the millet plant which after swathing and drying in the field, becoming very hard and possibly reducing the palatability of the forage. It is reported by Klein (2009) that inflorescence of the millet plant may result in development of bristles at maturity, thus reducing the palatability of the crop for the grazing animal. Subjective observation of the swathed millet in months of November and December during the grazing season of both years revealed that some plants were frozen and calves worked hard to apprehend the forage. This might also have reduced palatability of the swathed millet ultimately leading to reduced dry matter intake. Supporting this observation, Dietz (2008) reported that grazing of swathed millet by calves in Saskatchewan was discontinued because the millet swath froze and was hard to access and consume by grazing animals. An additional subjective observation in this trial showed that BR calves were sorting out the heads of the barley plant from the stem as the grazing period advanced resulting in enhanced palatability and leading to a possibly higher intake of nutrients. In a study at Mandan, North Dakota, USA, Karn et al. (2005) reported that limit grazing of swath using electric fencing and decrease in forage quality within the same area, saw animal selectivity increasing as the grazing progressed through winter.

3.5.4 Animal performance

Initial and final body weights of the calves are presented after 4% shrinkage. No difference ($P>0.05$) was observed for the initial body weights (SOT) of calves among the background treatments (Table 3.4) but BR and DL calves had a higher final body weight (EOT) compared to the calves in ML backgrounding system ($P<0.008$) (Table 3.4).

Table 3.4. Effect of back grounding system on performance of beef calves

	Treatment [z]				
Item	BR	ML	DL	SEM	P value
Initial BW (kg)[y]	217.7	218.1	218.3	3.44	0.99
Final BW (kg)[y]	297.4a	275.7b	293.2a	3.97	0.008
Average daily gain (kg)	0.84a	0.61b	0.79a	0.03	0.002

[z]BR =Calves grazing swathed barley; ML = calves grazing swathed millet; DL = calves bunk fed in drylot pens

[y]Initial and final body weights reported on a 4% shrink basis

a-b Means in rows with different letters differ ($P < 0.05$)

BL (0.84 kg $h^{-1}d^{-1}$) and DL (0.79 kg $h^{-1}d^{-1}$) calves had similar average daily gain (ADG) which were greater than the ML (0.61 kg $h^{-1}d^{-1}$) calves (P=0.002) (Table 3.4). Overall no differences were observed for total body weight gain between BR (79.7 kg) and DL calves (74.8) but ML calves gained significantly less ($P<0.0009$) than BR and DL calves. Differences in the performance of calves in BR, DL compared to the ML calves are attributed mainly to differences in feed quality and the weather variables affecting the DMI of calves in the different backgrounding systems. As discussed earlier, estimated DMI of BR and DL calves tended to be similar but higher than ML calves. This likely accounts for the lower performance of the ML calves. Rations were formulated based on forage and range pellet nutrient composition using CowBytes® with a targeted weight gain of 0.8 kg per day. Overall in the backgrounding period, according to NRC (2000) level 1 based on a diet containing 60% TDN, calves with a similar weight and ADG as the study animals were predicted to have DMI of 6.95 to 9.51 kg d^{-1} during the trial with an average of 8.19 kg per day. The barley swath calves had DMI similar to the predicted NRC (2000) requirement and performed as expected (Table 3.4). However, millet calves consumed 24.3 % less than the predicted NRC (2000) requirements, thus explaining the observed differences of 23.4% in the predicted and estimated ADG of ML calves over the 2 year period.

The BR calves in comparison to the DL calves consumed similar amounts of dry matter (8.1 kg $h^{-1}d^{-1}$ for BL 7.1 kg $h^{-1}d^{-1}$ for DL), 22% higher digestible energy intake and performed equally (0.84 kg $d^{-1}$for BL and 0.79 kg d^{-1} for DL) in this study. However, McCartney et al. (2004) reported that cows grazing swathed barley had similar levels of DMI (10.74 kg$h^{-1}d^{-1}$ for swath grazing, 11.74 kg$h^{-1}d^{-1}$ for traditional system) and 17.5 % higher digestible energy intake (DEI) but performed significantly lower compared to the silage and straw fed traditional system

(0.04 kg d^{-1} for swath grazing, 0.42 kg d^{-1} for traditional system). The differences observed by McCartney et al (2004) combined with the results of the current study suggests that maintenance energy (NEm) requirement of barley calves was higher due to exposure to environment than DL calves thus affecting the performance.

3.5.5 Finishing performance

Initial BW of BR calves at the start of finishing was 6.8 kg greater (P= 0.01) than the DL calves and 18 kg greater than the ML calves (Table 3.5). Initial BW for DL calves was 11.2 kg greater than the ML calves (P=0.01). No differences were found in the final BW among the calves in the background systems (P=0.079). However, mean DMI was 11.55 kg d^{-1} and was not (P=0.75) different among treatments**.** No difference were observed in ADG (P=0.38) and feed efficiency (P=0.28) among the treatments. This study was initiated with the aim to evaluate the suitability of the barley and millet for swath grazing in terms of their potential for winter grazing compared to feeding hay in traditional dry lot backgrounding system. In addition the objective was to evaluate the effect of backgrounding systems on the finishing performance and carcass characteristics of beef calves in western Canada. Even though no differences were found in finishing performance (ADG) of the calves among treatments (Table 3.5), an increase in the performance of the millet backgrounded calves at some stage of the finishing trial, relative to BR or DL calves would typically be expected based on similar final body weights, suggesting compensatory gain of the ML calves. Compensatory gain was reported by Hersom et al. (2004), where differences in the backgrounding ADG of calves grazing winter wheat and native range were mitigated during the finishing period where all animals were provided the same finishing ration. In the present study, an analysis was conducted to determine at what stage of the finishing period compensatory gain was exhibited by the ML calves.

Table 3.5. Effect of consuming barley swath, millet swath or hay during backgrounding on feedlot performance of beef calves in 2007-08 and 2008-09.

	Treatment				
Item	BR	ML	DL	SEM[z]	*P*- value
Start of test weight (kg)	330.0a	312.0b	323.2ab	3.94	0.01
End of test weight (kg)	610.5	603.1	606.5	7.54	0.79
Average daily gain (kg d^{-1})	1.70	1.73	1.69	0.03	0.38
ADG (%)[y]					
d 0-d28	0.34	0.32	0.30	0.03	0.41
d 29-d56	0.37	0.41	0.42	0.02	0.38
d 57-d84	0.50	0.58	0.52	0.04	0.06
D 85-d112	0.49	0.46	0.52	0.03	0.25
Days of feeding	158	161	162	3.16	0.22
Dry matter intake (kg)	11.58	11.59	11.48	0.11	0.75
Feed:Gain	6.83	6.72	6.84	0.05	0.28
US backfat thickness (mm)[x]					
Start of test	3.5a	2.5b	2.4b	0.58	0.03
End of test	12.1	11.6	11.3	0.35	0.32
Gain	9.2	9.2	9.3	0.55	0.93
US longissimus dorsi area (mm)[w]					
Start of test	50.5	47.3	50.6	2.05	0.06
End of test	84.6	82.6	85.5	2.34	0.18
Gain	32.3	33.6	33.0	2.86	0.86

[z] SEM = pooled standard error of mean

[y] Average daily gain as percentage of mean body weight

[x] Ultrasound measurements of subcutaneous fat thickness (SAS adjusted least square mean)

[w] Ultrasound measurements of *longissimus dorsi* area (SAS adjusted least square mean)

The analysis of ADG was presented as a percentage of mean body weight at each interval of the 28d feeding period (Table 3.5). This analysis revealed a tendency (P=0.06) for the ML calves to gain faster from d 57 to 84 of the finishing period compared to the BR and DL calves, suggesting compensatory gain of the ML calves (Table 3.5). The barley backgrounded calves had the highest BW gain for the first 30 d feeding period. White et al. (1987) also reported similar results, where steers (High BW gain) grazing winter wheat pasture during the backgrounding period had the highest BW gains and also exhibited the highest BW gains during the first 28d of a subsequent summer grazing period or feedlot finishing period. However no differences (P>0.05) were found in the gains for the entire finishing period compared to steers (Low BW gain) on winter wheat pasture. Even though statistical evidence of compensatory gain is lacking in the current study, a numeric difference was observed across an average of 158 d (year 1 & 2). The ML calves gained 6 kg more than the BR calves and 8 kg more than the DL calves during the finishing period. Barley backgrounded calves also had the greatest initial back fat compared to the ML or DL calves. Hersom et al. (2004) mentioned that growth rate and efficiency or metabolizable energy (ME) allowable daily gain of growing / finishing animals at a particular BW as predicted by level 1 of NRC (2000) decreases as body fat or body condition increases which was also observed in current study. Calves backgrounded on barley swath had the greatest initial backfat but gained numerically less than the calves backgrounded on millet swaths for the entire finishing period. Any restriction of nutrient intake such as palatability or accessibility during some portion of the growth process has been found to result in lower ME requirements than in an *ad-libitum* nutrient availability situation, leading to increased rate and efficiency of gain in the subsequent *ad-libitum* feeding phase (Phillips et al. 1991).

Variation in results have been well documented on the effects of different backgrounding systems with different nutrient restriction on the subsequent finishing performance and carcass characteristics due to differences in severity and duration of feed restriction (Choat et al. 2003; Klofenstein et al. 2000) Carsten et al. (1991) reported that steers limit fed a ration during backgrounding (0.04kg d^{-1} ADG) exhibited a compensatory gain 37% greater than those continuous fed during finishing. Choat et al. (2003) also reported that steers grazing native range gained 28 % less compared to animals grazing winter wheat over a 180 d backrounding period but finishing ADG was 7.4% greater for the native range backgrounded steers compared to the winter wheat backgrounded steers. This was also evident in the current study, where millet backgrounded calves had a numerically 1.76% and 2.36% greater ADG and 1.37% higher gain efficiency than the BR and DL calves during finishing. Lack of significant effect of compensatory gain of the ML calves during feedlot finishing may be due to length of the winter grazing period and that a lesser degree of restriction was imposed in this study. This increased growth can be exploited when lower growth during one phase of beef production coincides with time of low input and allows the expression of this growth when input cost are high (Drouillard and Kuhl, 1999).

There is the practice of assigning price discounts for feeder cattle in the industry, entering the feedlot with greater body condition (Smith et al. 2000). Based on data in current trial, price discounts of the calves grazing swathed barley (BR) having greater body condition may not be justified in relation to their subsequent finishing performance. Further, any factor affecting the forage availability or its quality may change the degree of compensation in grazing animals (Lewis et al. 1990) Similar to our results, Hershom et al. (2004) reported that steers grazing native range (with low ADG) or winter wheat (with high ADG) during backgrounding period had similar performance in the feedlot finishing phase. In contrast, Phillips et al. (1991; 2001) reported increased gains and improved feed efficiency during finishing for animals previously grazing dormant native grass (with low ADG) compared with steers grazing winter wheat (with high ADG) during the backgrounding period. It may be difficult to explain the variation in results of different experiments because of multifactorial causes which may include number of days animals were grazed, initial body composition, genetic, environment and performance of animals that were restricted and non-restricted in nutrient intake (Choat et al. 2003). Hershom et al. (2004) has mentioned that winter grazing also affects fat deposition in animals due to differences in energy intake which can be reflected by differences in marbling scores of animals. The initial differences in the ultrasound subcutaneous fat among the treatments in this study may be due to differences in energy (DE) intakes during the back grounding period.

3.5.6 Carcass characteristics

Various studies have been conducted to study the effect of winter gains on subsequent compensatory gain on pasture and feedlot performance (Choat et al. 2003; Hershom et al. 2004). However, no data is available with respect to investigating the carcass characteristics of animals which were back grounded on swath grazed cool or warm season annual crops. In this study, we also investigated the influence of backgrounding system in the rate of BW gain of calves grazing either swathed barley (cv Ranger), millet (cv Golden German) or alfalfa grass-legume hay in drylot during the winter on the carcass quality. However, no differences were observed for hot carcass weight (HCW) among the BR, ML or DL backgrounding systems (P = 0.68) (Table 3.6). Grade fat (P = 0.86), dressing percentage (P = 0.53), estimated lean yield (P = 0.45), *l.dorsi* area (P = 0.32), marbling score (P = 0.40 to 0.90), were also unaffected by backgrounding treatment.

Table 3.6. Effect of consuming barley swath, millet swath or hay during backgrounding on carcass characteristics of finishing calves (2007-08)

	Treatment				
Items	BR	ML	DL	SEM[Z]	*P*- value
Shrunk ship weight (kg)	617	607	612	13.6	0.89
HCW (kg)	359.5	349.6	357.1	8.23	0.68
Dressing percentage	58.0	57.5	58.2	0.46	0.53
Grade fat (mm)[y]	10.5	11.2	10.7	0.97	0.86
Estimated lean yield (%)[x]	59.7	58.5	59.2	0.67	0.45
L.dorsi area (cm^2)	96.0	93.5	93.7	1.28	0.36
Marbling score[w]					
Percentage with score 5	5.0	7.5	0.0	1.80	0.90
Percentage with score 6	2.5	5.0	10.3	2.20	0.40
Percentage with score 7	32.5	25.0	35.9	4.20	0.58
Percentage with score 8	60.0	62.5	53.8	4.50	0.73

[z] SEM = pooled standard error of the mean

[y] Grade fat is a measure of subcutaneous fat assessed perpendicular to the outside surface, within the fourth quarter of the rib-eye at the minimum point of thickness.

[x] Estimated lean yield = 63.65 +1.05 (muscle score)- 0.76 (grade fat)

[w] Marbling score : 5 = moderate, 6 = modest, 7 = small, 8 = slight, 9 = traces and 10 = devoid.

In this study, averaged over two years, BR and DL calves had greater (P<0.05) ADG (0.84 kg d^{-1} for BR and, 0.79 kg d^{-1} for DL) during backgrounding compared to the ML calves (0.60 kg d^{-1}). Lewis et al. (1990) also reported similar results in a Nebraska study where steers gained 0.28, 0.38 and 0.50 kg d^{-1} in low, medium and high gain winter grazing treatments. During finishing, steers were fed a common dry rolled corn and corn silage based ration, however no differences (P>0.05) were found in HCW, quality grade or yield grade, indicating no effect of winter gain (backgrounding) on carcass characteristics of the steers. In another experiment, Hershom et al. (2004) reported no differences in dressing percentage, 12th rib fat thickness, kidney, pelvis, heart fat (KPH), *longissimus dorsii area*, marbling score or yield grade of steers wintered on high gain winter wheat system (HGW), low gain winter wheat system (LGW) or native range. However, HCW was greatest for steers on HGW when slaughtered at a common back fat. In a second experiment, the authors (Hershom et al. 2004) found no difference (P>0.05) for any carcass parameter. The number of days on feed on average over 2 years were 87, 114, and161 for high, medium and low gain winter treatments respectively. However, Neel et al. (2007) has reported Angus steers exhibiting a low (0.23 kg d^{-1}), medium (0.45 kg d^{-1}) or high rate of gain (0.68 kg d^{-1}) during winter, affected carcass characteristics when slaughtered at equal time end points. Hot carcass weight, dressing percentage and USDA quality grades were greater (P<0.05) for high gain steers compared to low or medium gain steers. In this study *longissimus dorsi* area and quality grades were not affected by backgrounding treatments. These results are in agreement with similar studies (Phillips et al. 2004; Choat et al. 2003). As suggested by Capiten et al. (2004), differences in the results of experiments indicates that the effect of winter grazing on carcass characteristics varies and may be influenced by the type of forage grazed, age of the cattle, biological type of the cattle or different implant strategy employed.

3.6 Conclusions

Suitable environment conditions for barley during the growing season may lead to increased yield compared to millet. Utilizing swathed millet or barley results in reduced or similar animal performance compared to grass-legume hay fed in drylot during the backgrounding period. This can be attributed to differences in the dry matter intake (DMI) of calves which is influenced by the environment, animal and plant factors. Calculated DMI of millet calves was less than the NRC (2000) requirement for the desired weight gain. Forage intake of millet calves may have been influenced by plant structures (bristles present on millet heads), or frozen swath thus affecting palatability and preference. Backgrounding of calves on swathed barley, millet or grass- legume hay fed in drylot resulted in similar finishing performance and carcass characteristics. Partial compensatory growth was exhibited by the swath grazed millet calves during the finishing period. Traditionally, growing cattle from different backgrounding systems with high body conditions are discounted due to the anticipated lower gain during finishing (Choat et al. 2004). Results of the current study suggest that discounts of barley or grass-legume hay fed dry lot calves may not be justified as their growth was similar to millet calves during finishing period.

4.0 IN-SITU RUMEN DEGRADATION KINETICS OF THREE FORAGES USED (RANGER BARLEY, GOLDEN GERMAN MILLET AND GRASS-LEGUME HAY) IN BACKGROUNDING PROGRAMS

4.1 Introduction

Swathing and windrowing forage allows improved management and utilization by the animal compared to grazing the standing crop through the snow (McCartney et al. 2004).The grazing season of beef animals can also be extended by utilizing swath grazing of small grain cereals. This practice may result in savings through a reduction in cost associated with harvesting, handling and feeding compared to conventional drylot pen system (Johnson and Wand 1999; McCartney et al. 2004). According to NRC (1996), a grazing animal's maintenance energy (ME) requirements increase 16% as the daily mean temperature decreases from15^0 C to-15 ^{0}C. Extreme cold temperature leads to a decrease in dry-matter intake (DMI) and grazing time of cattle on native range. This indicates the importance of the available forage nutritive value to avoid the negative impact of cold stress on performance of grazing animals (Adams et al. 1986). McCartney et al. (2004) has reported that the nutrient level of swathed whole plant barley is sufficient to meet the minimum energy and protein requirements of beef cows in mid gestation. However, limited information is available about the potential nutritive value of swathed annual crops to meet the requirement of growing beef calves during winter in western Canada.

Performance of calves depends on maximizing dry matter intake (DMI). Daily DMI of grazing beef animals can be limited by the percentage NDF in the forage and the rate of fiber degradation in the rumen (Allen 2000). Previous studies have indicated that fiber concentration of the swathed forage increased and protein concentration and in vitro organic matter digestibility (IVDOM) decreased from September to February due to weathering (Volesky et al.

2002; Baron et al. 2006). This loss of nutrients may hamper the performance of the grazing animals. In chapter 3 (Table 3.3) results from the backgrounding trial showed that average daily gain (ADG) of beef calves was different among calves grazing barley swath, millet swath or consuming grass legume hay fed in drylot pens. Beef calves grazing barley swath had greater ADG ($p<0.05$) compared to calves grazing swathed millet or bunk fed grass-legume hay in drylot pens. Calf performance data may reflect a change in nutritive value of swathed crops or grass legume hay throughout the grazing season (October to January).Calves were limit grazed on the swathed forages for a 3 day period using electric fence. Consequently, nutritive value of the swathed forages may vary during the grazing period and may not be as constant in composition as the hay fed in the drylot over the same grazing period. Calves grazing in field systems may be selective and start consuming specific swathed plant component, the majority consisting of mature grain, leaving straw residue after they have moved to new graze area (Baron et al. 2006). Therefore, it is important to know how this variability in forage nutritive value affected the degradability and assimilation of the different nutrients in the rumen. Many studies have been conducted to examine the rumen degradation kinetics of barley grain and millet grain. Baron et al. (2006) reported the *in vitro* digestibility of whole plant barley swath in Alberta. However, information is lacking regarding rumen degradation characteristics of whole plant barley (cv Ranger) and foxtail millet (cv Golden German) compared to processed hay (grass-legume). Therefore, the objective of this experiment will be to determine the rumen degradation characteristics (DM, CP, and NDF) of each forage type collected at the start (SOT) and end of a backgrounding trial (EOT).

4.2 Material and Methods

4.2.1 Sample preparation

Samples of barley swath (cv Ranger), millet swath (cv Golden German) and processed grass-legume hay were collected at 7 different sampling dates throughout the grazing trial. The time frame includes pre and post swathing of field crops, and 5 dates during the backgrounding trial. Because of the physical limitation in handling the large number of bags in cows only those samples collected at start (SOT) and end (EOT) of the backgrounding trial were evaluated for degradation kinetics. All year one (2007-08) samples were ground with a 1 mm screen while half amount of second year (2008-09) samples were ground with 1 mm and the other half amount with 2 mm screen (Retsch ZM 100 , Haan, Germany).

4.2.2 Animals and diets

Four dry Holstein cows fitted with a 13 cm (internal diameter) rumen cannula (Bar Diamond , Parma, ID) were housed in the Livestock Research Facility at the University of Saskatchewan and were used for the measuring the rumen degradation characteristics. All cows were adapted to *ad-libitum* grass-legume hay for 21 days prior to the start of the in situ trial. Chemical composition of the grass legume hay was 91% DM, 9.5% CP (DM basis), 50.3% ADF (DM basis) and 69.7% NDF (DM basis). All the cows were provided *ad-libitum* feed to at 0800 and 1600 daily during the adaptation as well as experimental periods. Animals used in the experiment were cared for in accordance with the guidelines of the Canadian Council on Animal Care (1993).

4.2.3 In situ rumen incubation

Rumen degradation characteristics were determined using the nylon bag in situ technique as described by Yu et al. (2004). Two separate metabolic (in situ) experiments were conducted. In first experiment, extent of rumen degradation of three forages (barley, millet, and grass-legume hay) ground with 1mm screen and collected at start and end of trial over 2 years were determined. There were a total 12 treatments. In experiment two, samples from the second (2008-09) year were collected at the start and end of the grazing trial, ground with a 2mm screen and used to determine the rate and extent of degradation. In total there were six treatments.

Experiment 1: The procedure involved preparing 10 nylon bags (10 x 20cm; ANKOM company, Fairport, NY) containing 7 g of sample from each of the 12 treatments. Samples were incubated in the rumen at 24 and 48h. A total of 120 nylon bags were incubated to complete the first run, which was completed in three days. A total of three runs were completed in nine days incubating a total of 360 bags (Table 4.1).

Experiment 2: Twenty two nylon bags were prepared for each treatment (Table 4.1) for the incubation times of 0, 2, 4, 8, 12, 24, 48 and 72 hours. A total of 120 nylon bags were incubated to complete the first run of this experiment. Three runs were completed in 12 d incubating 360 bags excluding the 0 h bags. To get the sufficient amount of residue for chemical analysis after incubation, the numbers of bags were increased with the increase in incubation time in the rumen. The numbers of bags incubated were predicted based on previously published data for alfalfa and timothy (Yu et al. 2004). A polyester mesh bag (45 × 45 cm) attached to a 90 cm rope secured to the outside of the cannula opening was used for placing and keeping the bags in the ventral sac of the rumen.

Table 4.1. Summary of the experimental procedures for the *in situ* incubation experiments

	Experiment 1	Experiment 2
Treatments	Whole plant barley	Whole plant barley
	Whole plant millet	Whole plant millet
	Grass-legume hay	Grass-legume hay
Years	2	1
Sampling dates	SOT, EOT	SOT, EOT
Total treatments	12	6
Runs	3	3
Incubation times (h)	24, 48	0, 2, 4, 8,12, 24, 48, 72
Bags required	360 (120 per run)	396 (132 per run)

A weighted plastic bottle was placed in the mesh bag to facilitate the position of the bags in the rumen. Bags were incubated in the rumen according to the "gradual addition/all out" schedule. The maximum number of bags incubated in one animal was 30. A staggered incubation program was planned to incubate all the bags for the specified time period. All bags for each incubation time from all treatments were grouped together and randomly allocated for incubation in the rumen. This procedure was adopted until all the bags had been incubated for the first run. Three runs were carried out in both experiments and each run was treated as a replicate during the statistical analysis of the data.

After the incubation, all bags were removed from the rumen and placed in separate plastic buckets filled with cold water to remove rumen particulate matter and microbes and to stop the microbial activity. Repeated rinsing of the bags was done in 1000 ml of cool tap water until the rinse water was clear. Estimation of the soluble fraction (S) was determined after rinsing the 0 h bags along with other bags. All bags were placed on a metal tray for drying in a forced air oven at 55 ^{0}C for 48 h after squeezing out the excessive water from the bags. All residue samples were weighed after drying and removed from the bags. All residues were pooled according to run, treatment, sampling date, year, incubation time for chemical analysis. All pooled residues and original forage samples from the 2 experiments were ground to pass through a 1 mm screen (Retsch ZM 100, Haan, Germany).

4.2.4 Chemical analysis

Dry matter (DM) content of forage samples and in situ rumen residues was determined by drying at 135°C for 2 h (AOAC 1990; method 930.15). Crude protein of the forage was partitioned in to 5 fractions (Licitra et al.1996). Crude protein of forage samples and in situ rumen residues was analyzed using a 2400 Kjeltec analyzer unit (AOAC 1990). Acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN) were determined by Kjeldahl analysis of the ADF and NDF residues, respectively. Soluble protein was extracted with bicarbonate phosphate buffer solution. Neutral detergent fibre (NDF) of the forage samples and in situ rumen residues was analyzed with alfa-amylase without sodium sulfite using an ANKOM 2000 Fiber Analyzer (ANKOM Technology, Fairport, NY).

4.2.5 Rumen degradation models

Experiment 1: Percentage degradability of the dry matter (DM) crude protein (CP) and neutral detergent fiber (NDF) was calculated by the following equation:

$$\text{Degradability (\%)} = (A - B)/A \times 100$$

Where A is pooled weight of the samples incubated in the rumen for a given incubation time; B is the pooled weight of residues for a given incubation time.

Experiment 2: The proc NLIN procedure of SAS 9.1 (2003) using Gauess-Newton method of iterative least square regression was used to estimate the rumen degradation characteristics. The first order kinetic equation of Orskov and Mcdonald (1979) was used by fitting the percentage of DM, CP and NDF residues obtained from the *in-situ* incubation.

$$R(t) = U + D \times \exp(-K_d \times (t - T_0))$$

Where R(t) = residue (%) of the amount incubated material after t h of rumen incubation ; U = potentially un-degradable fraction (%); D = potentially degradable fraction (%); T_0 = lag time (h); K_d = degradation rate (% / h).

Effective degradability of DM, CP and NDF was estimated using non linear parameters (S, D, U and K_d) obtained from the above equation;

EDDM (g/kg) = S + D $_X$ $K_d/(K_p + K_d)$

Where S = soluble, or 'wash-out' fraction (g/kg), and $K_{p.}$ = estimated rate of outflow from the rumen (% h^{-1}). A K_p value of 4 % h^{-1} was used to represent the rumen turnover rate (Yu et al. 2004). EDCP and EDNDF were estimated like EDDM.

4.3 Statistical analysis

Experiment 1: A randomized complete block design using Proc mix procedure of SAS (2003) was used for the statistical analysis of the data. One way analysis of variance (ANOVA) was used and differences were considered significant when $P<0.05$ and trends indicated when $P<0.10$.The experimental model included year as block and effect of forages (Barley, millet, Hay) sampling date (Date) (SOT and EOT) and incubation time (24h, 48h) on ruminal degradability of DM, NDF and CP. A total of three replicates were used by taking each run as a single replicate.

Experiment 2: Proc mixed of SAS (2003) was used for analysis of variance data for the non linear variables. The model used for the analysis was:

$$Y = \mu + J + K + \gamma$$

Where Y is an observation of dependent variable; $\mu$is the population mean for the variable; J is the effect of forages (Barley, millet, Hay); K is the effect of sampling date (SOT and EOT); γ is the error associated with the observation. Means were separated by LSD when the F- test was significant ($P<0.05$).

4.4 Results and discussion

The chemical composition of the forages collected at the start and end of the backgrounding trial are presented in Table 4.2. There were no significant two or three way interactions other than forage x time on NDFD, therefore only main effects were discussed. The *in situ* DM and CP digestibility of swathed barley (barley) and millet (millet) was equal and greater ($P<0.05$) than grass legume hay (hay) (Table 4.3) at 24 h and 48 h of ruminal incubation. *In situ* NDF digestibility of millet was greater than barley and hay at both 24 and 48 h of ruminal incubation. DM digestibility of the barley was stable from the SOT to end EOT of the grazing period ($P>0.05$).These results were expected based on the similar level of the DM and chemical composition of samples collected at SOT and EOT indicating minimum weathering affect on the quality of barley. In contrast, Aasen et al. (2004) reported that in vitro organic matter digestibility (IVDOM) of swathed barley harvested at mid dough stage decreased 25% and 8% during the grazing period (September to April) in first and second year and remained constant in the third year of study.

Waldo et al. (1986) reported that NDF level of forage is the best predictor of the voluntary dry matter intake (VDMI) of the ruminants which determines the performance of the animal. However, Allen et al. (1996) reported that determination of VDMI based on NDF content of the forage only is inadequate and it varies with particle size, particle fragility and rate and extent of NDF degradation. Based on results of current experiment and previous literature, it is anticipated that dry matter intake of Millet grazed calves would be higher than Barley calves due to higher extent of NDF degradation of millet forage in rumen but dry matter intake of the millet calves was lowest (Table 4.3).

Table 4.2. Composition (%DM) of the barley swath, millet swath and grass-legume hay sampled at start on test (SOT) and end of test (EOT) over two years.

	DM	OM	CP	% of Total CP BSN[z]	NDIN[y]	ADIN[x]	NDF	ADF	ADL
Barley									
SOT	65.0	92.1	11.4	32.2	26.3	12.6	60.1	37.7	5.7
EOT	66.0	92.7	12.4	33.1	31.1	17.3	55.3	35.2	5.8
Millet									
SOT	44.1	88.7	14.3	36.1	35.3	11.9	63.3	39.2	6.1
EOT	59.2	89.6	12.8	39.3	38.7	17.1	66.7	43.5	6.0
Hay									
SOT	89.7	94.5	8.2	28.5	47.6	17.4	73.3	47.9	8.2
EOT	82.2	94.7	8.1	28.0	47.0	18.1	72.6	49.5	9.2

[z]BSN= Soluble N in borate phosphate buffer
[y]NDIN= Neutral detergent insoluble nitrogen
[x]ADIN= Acid detergent insoluble nitrogen

Table 4.3. The extent of DM, CP, NDF degradation of forages (barley swath, millet swath and hay) collected on start and end of backgrounding trial for two years at 24 and 48 h of rumen incubations

Item	Forage				Date [z]			Time [y]		
	Barley	Millet	Hay	SEM[x]	SOT	EOT	SEM	24h	48 h	SEM
DMD	58.9a	57.5a	46.4b	0.96	54.6	53.9	0.81	48.6b	59.9a	0.81
CPD	68.9a	67.4a	44.9b	1.30	60.6	60.2	1.06	57.0b	64.0a	1.06
NDFD	40.1b	46.8a	33.7c	3.20	41.7a	38.7b	3.13	32.2b	48.2a	3.13
P value										
	Forage	Date	Time	F×D	F×T	D×T	F× D×T			
DMD	<.0001	0.49	<.0001	0.25	0.12	0.36	0.58			
CPD	<.0001	0.74	<.0001	0.13	0.21	0.32	0.77			
NDFD	<.0001	0.02	<.0001	0.58	0.02	0.58	0.24			

[Z] Date = SOT = start of test; EOT = End of test
[Y] Time= 24h= 24 hour of incubation; 48h= 48 hour of incubation
[X]SEM = pooled standard error of mean
a-b Different letters in the same column indicate significant differences (p <0.05)

This reflects the negative ralationship between the degradation of DM, NDF and CP of the millet forage relative to the performance of millet grazed calves during backgrounding trial. Dry matter intake (DMI) of low digestibility feeds is limited by physical distention in the gastrointestinal tract. A decrease in particle size of low digestible forage by grinding generally increases the DMI due to reduction in initial volume and retention time in reticulorumen (Allen 1996). Rumen degradation characteristics of DM, CP and NDF of the hay were lowest among the three forages. However, DMI of the hay fed calves was equal to barley calves (Table 3.3). This may be due to the reduced particle size of hay. This questions the reliability of formulation of diet for a desired target weight gain in grazing beef animals based on the chemical composition of forage and implies the importance of knowledge of physical properties of forage and preference and selectivity of animal prior to the diet formulation.

The *in situ* degradation kinetic parameters for DM, NDF and CP degradation of forages sampled at end and start of backgrounding trial in year 2 are shown in Table 4.4. Barley, millet and hay had similar soluble DM fractions (S). However, the potential degradable DM fraction (D) was highest in millet, intermediate in barley and lowest in hay ($p<0.05$). No significant differences were observed in the rate of degradation of slowly degradable fraction of DM between the forages. However, numerical rate of degradation was highest in barley (7.6%h^{-1}), intermediate in hay (6.6%h^{-1}), and lowest in millet (5.5%h^{-1}).

Effective degradability of DM (EDDM) of barley and millet were similar ($p<0.05$) but higher than hay. Effective degradability is a function of the total degradable fraction, rate of degradation and passage rate (Yu et al. 2004). Therefore, although the slowly degradable DM fraction of millet was higher than barley, its effective degradability of DM was similar due to numerical slow rate of degradation of millet. Results of 24 and 48h DM rumen degradation of forages (experiment 1), where extent of degradation of barley and millet was similar and higher than hay (Table 4.3) further substantiated these results. The low effective DM degradability of hay was due to a reduced slowly degradable fraction of DM and low extent of degradation (experiment 1). This demonstrated that differences in the dry matter intakes of calves during the backgrounding period are not a result of differences in the potential digestibility but some other factors might be affecting it. Probable factors include physical characteristics of the plant, individual preference and selectivity of the animal for the particular plant species. *In situ* soluble DM fraction of forages at the beginning (SOT) was higher ($p<0.05$) than end (EOT) of grazing trial. No difference was observed in slowly degradable fraction and rate of degradation due to sampling date. Effective DM degradability was similar at SOT and EOT as result of numerical higher rate of degradation at EOT than SOT even though the soluble fraction of DM was higher at SOT than EOT. Baron et al. (2006) observed a linear decrease in the IVDOM of barley swath from 60.5% to 54.4% from September to February grazing period in contrast to consistent level of EDDM in this study. This supports our observation that BS and MS were least affected by weather and trampling by animals leading to unaltered chemical composition during the grazing period resulting in no change in digestibility from start to end. Effective degradability of DM (EDDM) for whole plant barley swath (53.1% Table 4.4) cut at a similar stage of maturity (Soft-dough) in the current study is less than the *in vitro* organic matter digestibility (IVDOM) value of 61.5% averaged over the four years of the grazing trial reported by Baron et al. (2006).

Barley and millet have similar and higher *in situ* soluble CP fractions than hay ($p<0.05$). Rate of degradation of CP of millet and hay were similar and less than barley ($p<0.05$) but no differences were observed for slowly degradable fraction of CP between the forages.

Table 4.4. ***In situ*** **rumen degradation kinetics for forages (barley swath, millet swath and grass legume hay) collected on different dates during the second year of back grounding trial**

	Forage[z]			Date[y]			P value		
Parameters	Barley	Millet	Hay	SOT	EOT	SEM[x]	Forage	Date	Forage × Date
DM									
S (%)	24.5	23.4	23.5	25.1a	22.1b	1.01	0.50	0.001	0.15
D (%)	44.4b	50.2a	39.6c	44.1	45.3	1.39	<.0001	0.30	0.06
K_d (%/h)	7.6	5.5	6.6	5.6	7.3	1.35	0.30	0.14	0.26
% EDDM	53.1a	52.4a	46.2b	50.7	50.5	1.47	0.0009	0.86	0.06
CP									
S (%)	30.1a	36.3a	22.2b	31.3	27.7	3.04	0.002	0.16	0.07
D (%)	44.7	40.4	46.0	42.2	45.2	3.71	0.32	0.33	0.01
K_d (%/h)	13.6a	6.6b	8.4b	8.0	11.0	1.86	0.007	0.06	0.07
% EDCP	61.0a	57.3a	46.3b	54.3	55.3	2.85	0.0007	0.66	0.18
NDF									
S (%)	3.43a	0.21c	1.05b	0.91b	2.2a	0.30	<0.0001	0.0002	<0.0001
D (%)	53.6b	66.8a	50.5b	57.8	56.1	1.91	<0.0001	0.29	0.07
K_d (%/h)	5.7	5.3	6.6	5.5	6.3	1.83	0.78	0.59	0.04
% EDNDF	27.8ab	31.4a	23.8b	27.0	28.4	2.77	0.05	0.53	0.22

[Z]Forage = BR =barley swath; ML= millet swath; DL =grass –legume hay
[Y]Date (Sampling date) SOT = start of test; EOT = End of test
[X]SEM = pooled standard error of mean
a-b Different letters in the same column indicate significant differences (p <0.05)

Effective degradability of CP of barley and millet was similar and higher than hay ($p<0.05$) due to higher *in situ* soluble CP fractions of barley and millet than hay. Even though the rate of degradation of millet was lower than barley still, effective degradability of millet and barley was similar. Reason could be due higher level of CP in millet than barley and similar extent of degradation as evident from first experiment. Effective degradability of CP of three forages was similar at SOT and EOT of the grazing trial due to similar *in-situ* soluble, slowly degradable fraction and rate of degradation of CP at SOT and EOT.

The *in situ* soluble NDF fraction was highest for barley, intermediate for hay, and lowest for millet ($p<0.05$) (Table 4.4). Slowly degradable NDF fraction of barley and hay was similar and lower than millet ($p<0.05$). A difference in the effective ruminal NDF degradability of the three forages likely reflects the differences in the slowly degradable NDF fraction. No differences were observed in effective ruminal degradability among three forages at SOT and EOT of the grazing period due to similar in-situ slowly degradable fraction and rate of degradation of NDF in all forages.

4.5 Conclusions

In situ study results showed that barley and millet have equal and greater rumen dry matter degradability than hay. This may be due to equal CP and NDF degradability of millet and barley and higher than hay. Based on these results, it can be inferred that substrate (nutrient) availability with the grazing of barley and millet will be equal and greater than hay provided all the other variables constant. Degradation kinetics (DM, CP and NDF) of forages collected at start (SOT) and end (EOT) of backgrounding were similar indicating minimum change in the chemical composition of forage due to trampling, weathering or any other factors. Negative correlations between the performance (dry matter intake) of the calves grazed millet swath during backgrounding trial and millet forage degradation kinetics introduced a new challenge for the balanced diet formulation just based on the chemical composition of the forage.

5.0 ECONOMIC ANALYSIS OF BACKGROUNDING SYSTEMS

5.1 Introduction

Swath grazing is an alternate feeding technique where forage is cut and left in the windrow for controlled grazing by animals in order to lower the production cost (Bowman and Sowell 2003). This technique has been adopted in many areas of the United States and Canada to reduce the cost of feeding beef cattle during winter (Surber et al. 2001). This is achieved through reducing the cost linked with mechanical harvesting, handling, and feeding and manure removal compared to conventional drylot feeding systems (Johnson and Wand. 1999). Several studies have been conducted to evaluate the economics of using different annual crops for grazing over the winter with the intent of reducing the feeding cost in different regions of the Canadian prairies. In Alberta, swath grazing cost of whole plant barley is reported to be around $70 per cow less compared to traditional drylot feeding over a 100 day grazing period (McCartney et al. 2004). In the same study, these authors reported grazing and yardage costs were reduced by 50 and 79 % respectively with 38% less labor cost compared to bale feeding, silage fed traditional drylot systems (McCartney et al. 2004). McCaughey et al. (2002) in Brandon, Manitoba evaluated the potential of several corn varieties for standing and swath grazing. They found that the high cost of seed and herbicide along with difficulty in swathing the corn crop rendered it unsuitable for swath grazing. At Lanigan, Saskatchewan, Lardner (2004a) compared the potential of swath grazed forage corn and barley for weaned beef calves and reported that total crop production expenses for corn were 67% higher, however cost of gain ($2.15 per kg for corn vs. $2.26 per kg for barley) was similar for both crops. Lardner (2004a) concluded high crop production expenses were responsible for the high cost of gain (COG) in both crops and backgrounding of calves on conventional drylot system could have been more cost effective.

Lardner (2004b) also reported cost of gain of calves backgrounded on foxtail millet (cv Golden German) to be around $0.60 per kg however the grazing period was only 26 days. Based on this data, the author suggested that for better economic gain of calves, total grazing period should be at least 60 days. Kelln (2010) reported that the daily winter feeding cost of cows on swath grazing was 23% and 55% lower compared to bale grazing and drylot feeding systems at Lanigan Saskatchewan over a 2 year period respectively. In the current economic climate where grain prices are rising, producers may choose to utilize a forage (swath graze) based ration for backgrounding calves instead of the high grain based traditional drylot system (McCartney et al. 2008). However, the high variability in COG for animals grazing swathed cool (oat and barley) or warm (corn, sorghum and millets) season annual crops in different regions of western Canada may discourage producers from these systems. Therefore, a more detailed grazing research study evaluating the economics of growing and grazing these crops is required in regions having suitable agronomic and climatic conditions.

5.2 Material and Methods

Detailed description of the crop production and grazing animal management including has been discussed in section 3.2.2 and 3.2.7 of chapter 3.

For the backgrounding study, the economic comparison of different backgrounding systems included costs associated with crop production and grazing management of the animals. These systems incorporated the cost associated with labor, machinery, yardage and raw material such as seed, fertilizer and herbicide. For the feedlot study, costs associated with feed, machinery and yardage only were included in the analysis. Infrastructure cost such as initial capital expenses, maintenance of temporary electric fences, shelters, maintenance of temporary waterers in case of swath grazing treatments were excluded from the analysis. Establishment costs of bunk, fencing and water in drylot and feedlot were excluded from the economic analysis. These were deemed outside the scope of this study and therefore were not included.

Feed was prepared on site for the extensive backgrounding systems (swath graze barley; swath graze millet), therefore no feed transportation charges were incurred in these systems. Costs were calculated by system and were reported as cost per head per day. In the drylot and feedlot, due to the storage at the feed site, no extra cost was associated with hauling the feed, but the purchase, processing, and supplying the feed was included.

Equipment costs were calculated using Saskatchewan Ministry of Agriculture's Farm Machinery Custom and Rental Rate Guide (SMA 2008 & 2009). Costs associated with repair, fuel, lube /oil were considered as total variable costs and equipment cost was determined by multiplying the total cost per hour by the time spent using the equipment. Total time spent on feeding was calculated by averaging the time spent on the entire feeding process during 2 consecutive days. Individual equipment used and time spent using the equipment was measured after observing the various activities during the feeding process. Cost of labor was \$15 hour $^{-1}$ and rate for manure removal were estimated at \$0.04 $hd^{-1}d^{-1}$. Labor rates were similar but manure removal rates were \$0.01 $hd^{-1}d^{-1}$ higher compared to past studies (Jungnitsch 2008; Kelln 2010) conducted at the same location.

5.2.1 Backgrounding trial

5.2.1.1 Crop production expenses

Crop production cost for the barley and millet crops are listed in Table 5.1.

Table 5.1 Barley and millet crop production costs in extensive grazing systems over two years

	2007-08		2008-09	
	Barley	Millet	Barley	Millet
	……………………………$ha^{-1}……………………………			
Land preparation	15.00	15.00	18.00	18.00
Pre-seed herbicide	29.80	29.80	25.75	25.75
Post-seed herbicide	20.00	20.00	15.00	15.00
Seed	27.50	37.50	27.50	37.50
Seeding	32.50	32.50	37.50	37.50
Fertilizer	22.50	22.50	45.00	45.00
Swathing	20.00	20.00	25.00	25.00
Land rolling	10.00	10.00	12.50	12.50
Trucking	7.50	7.50	7.50	7.50
Total	184.8	195.0	213.7	223.7

All operational costs were based on custom rates from the Saskatchewan Farm Machinery Custom and Rental Rate Guide (SMA 2008 & 2009). Total cost for the swath grazed backgrounding systems (barley; millet) included land preparation, herbicide , pre-seed and post herbicide application , seed, seeding, fertilizer, land rolling, swathing, and trucking. Commodities such as seed, fertilizer and herbicide prices were based on their purchased price. For the drylot treatment, processed grass legume hay was purchased locally and priced at $0.079 per kg in 2007 and $0.085 per kg in 2008.

Crop production costs were similar for swathed barley and millet in 2007-08 ($184.8) barley and $195.0 per hactare millet) and 2008-09 ($213.7 barley and $223.7 per hactare millet). Aasen et al. (2004) reported the barley crop production expenses of $140 per hectare based on commodity prices of 1998 at Lacombe, Alberta. On average cost of production of barley and millet swath were $0.035 per kg DM and $0.058 per kg DM over two years respectively based on cost of production per hectare and total swath dry matter produced. In the current study, second year (2008-09) crop production costs of barley increased by 16% and millet 14% due to rising commodity prices (Appendix Table B.1). The major variable affecting the increase was doubling of the fertilizer price ($0.365 in 2007 and $0.795 in 2008) in the second year.

5.3 Results and Discussions

5.3.1 Cost of gain analysis for backgrounding

Total COG including feed costs, direct costs (bedding) and yardage costs are reported in Table 5.2. Feed costs included the expenses associated with production or purchase of forage, supplementation, mineral and salt fed to the animals. Total cost of the feed or ration was determined by the ingredient production or purchase costs per kg of feed produced multiplied by the amount (kg) of the ingredient consumed. In 2007-08, feed cost was greatest for the drylot backgrounding system ($1.17) followed by swathed grazed barley ($0.96) and least cost for swathed grazed millet ($ 0.90) (Table 5.2).

Table 5.2 Total cost of gain of 3 different backgrounding systems over 2 years

	BR		ML		DL	
Item	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
	...........................$ $hd^{-1}d^{-1}$........................					
A. Feed costs						
Forage[z]	0.26	0.17	0.20	0.31	0.47	0.55
Supplementation	0.65	0.63	0.65	0.63	0.65	0.70
Vitamin- mineral salt	0.05	0.07	0.05	0.07	0.05	0.07
Total	0.96	0.87	0.90	1.01	1.17	1.32
B. **Direct cost**						
Bedding	0.02	0.02	0.02	0.02	0.04	0.04
Total	0.02	0.02	0.02	0.02	0.04	0.04
C. Yardage cost						
Machinery (inc. fuel)	0.37	0.23	0.37	0.23	0.48	0.48
Labour	0.08	0.09	0.08	0.09	0.15	0.17
Building &corral repair	0.01	0.01	0.01	0.01	0.01	0.01
Depreciation	0.01	0.01	0.01	0.01	0.02	0.02
Manure cleaning	-	-	-	-	0.04	0.04
Total	0.47	0.34	0.47	0.34	0.70	0.72
Total production cost (A+B+C)	1.45	1.23	1.39	1.37	1.91	2.08
Total gains (kg/d)	0.86	0.84	0.56	0.67	0.70	0.89
Cost of gain ($/kg)	**1.68**	**1.46**	**2.48**	**2.04**	**2.72**	**2.33**

[z]Forage = BR=barley swath; ML=millet swath; DL= grass-legume hay fed system

This was due to lower DM feed (forage) cost ($0.20 $hd^{-1}d^{-1}$) and lower DM consumption of millet grazed calves. In 2008-09, total feed cost was greatest for drylot ($1.32) followed by millet ($1.01) and least for the barley ($0.87) backgrounding system. The reason for this is due to the high crop production cost of growing millet and the higher forage ($0.55 $hd^{-1}d^{-1}$) cost of drylot calves. Overall feed costs of drylot backgrounding system were greater due to higher hay costs in both years of study.

Kelln (2010) reported feed costs of swath grazed barley ($0.36 $hd^{-1}d^{-1}$ and $0.40 $hd^{-1}d^{-1}$) and in drylot wintering ($0.62 $hd^{-1}d^{-1}$ and 0.97 $hd^{-1}d^{-1}$) of cows that were lower than the current study over a two year period. These higher costs likely due to the extra supplementation of the growing calves for achieving the targeted weight gain. In the Kelln (2010) study, only maintenance needs of the cows were met without any supplementation. A reason for greater feed cost in the drylot system in our study, compared to Kelln (2010) may also be due producing the hay at the study site compared to purchasing the hay from the outside source in current study.

Direct costs including cost of bedding (straw) was higher for the drylot ($ 0.04 $hd^{-1}d^{-1}$) compared to the swathed grazed millet or barley ($ 0.02 $hd^{-1}d^{-1}$) backgrounding system over two years. This was due to the use of residual or spoiled feed as bedding in swathed grazed backgrounding systems thus decreasing the need of replacement of bedding.

Yardage cost included the machinery (equipment) used along with fuel charges, labor for the different operations, repairs of building and corrals, depreciation, and manure cleaning expenses. In the field, more equipment was used to move windbreaks, fences and provide water to the calves, which resulted in increased equipment costs associated with the extensive feeding systems during the first year of study (2007-08). However, during the second year (2008-2009) equipment costs were reduced since less equipment was used to provide water and move fences but for drylot backgrounding system, machinery cost was similar over 2 years due to most of the operations being similar. For both years of study, labor was lower for swath grazed field systems compared to the drylot backgrounding system. Grinding of hay and feed mixing along with the daily supply of feed in bunks required time and labor. Maintenance of buildings and corrals was considered similar however, depreciation was slightly higher in drylot because of higher animal density with the infrastructure. Total yardage costs of BR and ML was equal and 77% less than DL backgrounding system. This was due to 60 % and 50% lower machinery and labor costs for BR and ML compared to DL. Similarly, McCartney et al. (2004) reported 38 % less labor for barley swath grazing compared to traditional bunk fed cows.

Total production cost was similar for millet over two years, but for barley a lower cost was observed in the second year due to lower feed and yardage costs. Total cost of production was greater in drylot backgrounding system (Table 5.2) due to higher feed and yardage cost. Jungnitsch (2008) and Kelln (2010) have reported the average cost of production in drylot wintering systems for cows at \$1.31 $hd^{-1}d^{-1}$ and \$1.58 $hd^{-1}d^{-1}$ over two years respectively at the same location, whereas in current study average production cost of drylot backgrounding calves is \$1.99 $hd^{-1}d^{-1}$.These differences are due to the higher feed cost associated with supplementation of calves.

The value of ungrazed feed was not considered in following spring in the extensive backgrounding systems. This could have influenced the overall cost of production. There is an issue with feed residue which influences the economic cost. An increase in soil fertility was observed due to retention of soil nutrients leading to increased production in subsequent crop production as a result of spread of manure and urine in extensive backgrounding systems (Kelln 2010). This will mitigate the negative impact of feed wastage and possibly lead to environmental friendly beef production. Total cost of production would have been reduced further in the swath grazed barley and millet backgrounding systems if the stocking rate would have increased in the current study as suggested by McCartney et al. (2008). Cost of gain (COG) of all three backgrounding systems was higher in 2007-08 compared to 2008-09. This is due to higher yardage costs for BR and ML, and lower daily gain (0.70 kg per day vs 0.89 kg per day) of DL calves in first year. The swath grazed barley backgrounding system had 43% and 60.5% lower cost of gain compared to swath grazed millet and drylot. Higher cost of gain for millet compared to barley even with similar cost of production is due to lower daily gain (0.61 kgd^{-1} millet; 0.85 kgd^{-1} barley) of the millet grazing calves. Drylot calves had similar daily gain to barley however COG was greater due to 48% higher total cost of production in the drylot backgrounding system.

5.3.2 Cost of gain analysis for feedlot finishing

Total cost of production for feedlot finishing incorporated feed costs, direct costs (bedding), yardage costs and based on the daily gain (kg d^{-1}), cost of gain (COG) was estimated (Table 5.3). Direct cost (bedding) and yardage costs were similar over the 2 years. Therefore, any variation in feed ingredient cost would affect the total cost of production during the finishing period. The calculated cost of feed was determining by the contribution of an ingredient in the ration multiplied by the price of individual ingredient. There was no difference in the total feed cost among the three backgrounding treatments in each year of study. However, in the second year (2008-09), feed cost was lower because of lower barley price (Appendix Table B.2). Finishing COG for swath grazed backgrounding calves was lower in 2008-09 compared to 2007-08, due to lower production cost and higher daily gain (Table 5.3).

Table 5.3 Total cost of gain for finishing						
	BR		ML		DL	
Item	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
	...........................$ $hd^{-1}d^{-1}$........................					
A. Feed costs						
Barley grain	1.42	1.19	1.47	1.20	1.46	1.19
Silage	0.15	0.23	0.15	0.23	0.15	0.23
Oat	0.29	0.09	0.28	0.08	0.29	0.08
Supplement	0.29	0.41	0.29	0.40	0.29	0.40
Canola meal	0.17	0.26	0.17	0.24	0.17	0.24
Hay	0.04	0.06	0.04	0.06	0.04	0.06
Straw	0.02	0.01	0.02	0.01	0.02	0.01
Total feed cost	2.38	2.25	2.42	2.22	2.42	2.21
B.Direct cost						
Bedding	0.01	0.02	0.01	0.02	0.01	0.02
Total	0.01	0.02	0.01	0.02	0.01	0.02
C.Yardage cost	0.45	0.45	0.45	0.45	0.45	0.45
Total production cost (A+B+C)	2.84	2.72	2.88	2.69	2.88	2.68
Total gains (kg/d)	1.68	1.71	1.76	1.69	1.71	1.67
Cost of gain ($/kg)	**1.69**	**1.59**	**1.63**	**1.59**	**1.68**	**1.60**

Millet (ML) backgrounding system calves finishing COG was similar over 2 years and lowest among all 3 backgrounding systems due to higher daily gains (1.73 Millet vs 1.69 kgd^{-1} barley and drylot) compared to BR and DL.

5.4 Conclusions

To maintain the profitability of the North American beef industry, it is mandatory to reduce the production cost per unit of meat produced (Barkema and Drabestott 1990). On average, a swathed barley backgrounding system resulted in a 43 and 60.5 % lower COG compared to a swathed grazed millet or drylot respectively. Swath grazed millet backgrounding system had a similar cost of gain compared to the traditional drylot backgrounding system. The lower cost of gain of backgrounding calves when grazing swathed barley provides a means of reducing the operation cost compared to feeding grass legume hay in a drylot backgrounding system. No benefit in the COG for backgrounding was seen between swath grazed millet and drylot backgrounding systems. However, the benefit experienced in this extensive system in terms of manure applied in field, reduced yardage costs and anticipated compensatory gain could outweigh the higher cost of gain in the drylot system.

Finishing cost of gain was similar for the calves from all the three backgrounding systems. This was expected based on the similar dry matter intake of calves with same ingredients thus reduced the chance of variation in costs.

6.0 GENERAL DISCUSSION AND CONCLUSIONS

This study was initiated with the motive of finding an alternative to the conventional drylot backgrounding system (high grain based) for beef producers who are faced with high grain prices. Any system should be viable, reduce the overall cost of production, maintain an increase in revenue and provide the consumer with acceptable quality meats. Such a system could ensure long term sustainability of the beef industry. Previous studies have reported that cool season annuals like oat and barley seeded in third week of May and swathed in early August in the soft dough stage meet the nutrient requirements of pregnant beef cows during winter (May et al. 2007; McCartney et al.2004). These studies also reported that savings of about 50% could be realized through reduced feed harvesting, handling and feeding costs as well as reduced costs of manure removal and labor (McCartney et al. 2008). McCaughy et al. (2002) reported that Golden German millet crop is more suitable for high rainfall and Dark Brown soils and was a good alternative crop for swath grazing in winter for well adapted animals in areas having summer temperatures of about 32-35^{0}Celcius. Lardner et al. (2004a) reported that cost of gain for backgrounding of calves grazing millet swath during winter was \$0.52 kg^{-1} which was much lower than the drylot (\$1.43 kg^{-1}) backgrounding system for a grazing period of 26 days.

Based on the outcome of these studies, a two year trial was conducted with the objective to evaluate calf performance, forage utilization and changes in forage quality as fall weaned calves grazed barley swath, millet swath or fed grass-legume hay in the drylot during winter and their subsequent effects on finishing performance and carcass characteristics . Further, a digestibility study was conducted to evaluate the *in-situ* rumen degradation kinetics of the three forages by using four ruminally cannulated dry cows fed a hay based diet. Finally, the economic analysis of the different backgrounding systems was conducted to analyse the cost of gain for backgrounding and finishing period. Results of the two year winter grazing trials revealed that, grazing of millet swath by calves during the backgrounding period resulted in lower ADG ($p<0.05$) compared to grazing swathed barley or grass legume hay in drylot pens. This result is explained by the observation that dry matter intake (DMI) ($p=0.11$) of calves tended to be similar for the BR and DL calves and lowest for ML calves. Forage analysis revealed that digestible energy of barley swath was highest (2.59 Mcal kg^{-1}) and lowest for grass legume hay (2.23 Mcal kg^{-1}) with intermediate value for millet swath (2.35 Mcal kg^{-1}). Dry matter intake is negatively correlated with NDF when intake is limited by fill and positively correlated when intake is limited by energy (Allen 2000). To explain the differences in DMI among treatments especially lower DMI of ML calves, the digestible energy intake (DEI) and NDF intake (NDFI) of calves was determined in different backgrounding systems. Digestible energy intake (DEI) tended ($P=0.13$) to be highest for the BR calves (22.9 Mcal $h^{-1}d^{-1}$) and lowest for the ML calves (16.8 Mcal $h^{-1}d^{-1}$) and intermediate for the DL calves (18.7 Mcal $h^{-1}d^{-1}$) with similar results for NDF intake ($p=0.17$) (Table 3.3). These results suggested that neither energy nor fill effect was responsible for lower DMI of ML calves. It was concluded that the possible reason for the lower DMI of ML calves may be the physical characteristics of the plant (bristles) and inaccessibility of the frozen swath (subjective observation) or differential preference of the animal. No difference was observed in the feedlot performance and carcass characteristics of the calves among the three backgrounding systems. Calves grazed swathed millet (ML) had compensatory gain during the finishing period. This suggests that with grazing of swathed millet results in revenue loss in terms of lower gain during the backgrounding phase, however this was mitigated at the end of finishing period and overall cost of operation will remain same.

In order to substantiate our performance results from the backgrounding trial, an *in-situ* rumen degradation (DM, CP, and NDF) study was conducted. The objective was to evaluate the extent and rate of degradation of three forages which might have influenced the DMI thus leading to differences in performance of calves. Results of the *in situ* rumen degradability trial showed that effective degradability of DM and CP were similar for barley and millet but greater than grass legume hay while NDF degradability of millet was greater than that of barley or grass legume hay indicating negative correlation between the rumen degradation of forage and resulting DMI of calves.

A decrease in particle size of low digestible forage by chopping generally increases the DMI due to reduction in initial volume and retention time in reticulorumen (Allen 1996). Possible reason for higher DMI and ADG of DL calves fed processed grass legume compared to ML calves hay might be due to higher passage rate due to small particle size. Based on the chemical composition and *in situ* rumen degradation kinetics, it is concluded that swathed millet was as good as swathed barley for use as base forage during backgrounding trial. Lower dry matter intake leads to poor daily gain of swathed millet grazed calves, suggesting some factors other than *in situ* digestibility might be responsible for the outcome of the backgrounding trial. More research is needed to further analyze the factors influencing the reduced dry matter intake of ML calves. Current trial observations suggest factors influencing palatability of millet (cv Golden German) particularly the physical characteristics of plant should be investigated.

Cost of gain for the barley swath grazed backgrounding system calves was 43 and 60.5% lower compared to a swath grazed millet or drylot system, respectively (Table 4.2). It can be suggested that backgrounding of fall weaned calves on swathed barley is an efficient management technique as conventional grass legume hay fed drylot system to meet the nutrient requirement of the developing calves. No adverse effects on health or carcass quality were noted. Management of the swath grazing systems is critical for efficient production as heavy snowfall and cold temperatures may impact animal performance. These climatic variables will also dictate the accessibility of the forage by the animal as well as quality of the forage and ultimately animal performance. This indicates that when backgrounding cattle under typical western Canadian winter condition, just relying on extensive (BR and ML) backgrounding systems will always remain a challenge and have a certain degree of risk. Therefore, a backup feeding plan is always necessary for the beef operation. However, based on the operational requirement, environmental conditions, and economic benefit associated with these extensive systems, producers will have enormous opportunity to choose an optimal feeding system for long term sustainability of their operation.

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8.0 APPENDICES

8.1 Appendix A

Table A.1 Mean monthly temperature and precipitation at the study site at Lanigan, Saskatchewan, Canada

	Temperature[z]			Precipitation		
	^{0}C			Mm		
	2007	2008	30-yr[y]	2007	2008	30-yr
January	-15.2	-15.4	-16.7	31.6	12	17.5
February	-16.2	-16.5	-12.4	18	6	10.9
March	-7.5	-11.7	-5.8	17.2	7	17.1
April	10	5.7	4	6.6	23.6	30.3
May	12.8	7.8	11.3	55.8	12.2	53.5
June	12.5	16.7	15.9	55.6	73	83.9
July	23.1	19.7	18.1	27.6	82.2	66.1
August	17.3	20.2	17.2	42	55	53
September	12.3	13.2	11.3	29	16	42.6
October	5.3	7.9	4.5	11.4	46.9	28
November	-9	0.9	-6	51	12.5	13
December	-17	-16.3	-13.9	-	16	18.6
January[x]		-19			17.2	

[z] Obtained from environment Canada

[y] 30 year average at Lanigan, Sakatchewan, Canada

[y]January= January 2009

Table.A.2 Chemical composition of the mineral & vitamin premix fed to calves (Feed Rite *RITE MINS* Beef Cattle 2:1 No- Salt mineral &vitamin premix ; (Feed Rite Ltd, Humboldt, SK, Canada)

Element	**Concentration**
Calcium	20.0 %
Phosphorus	10.0 %
Cobalt (mg/kg)	70
Iodine (mg/kg)	200
Copper (mg/kg)	3000
Manganese (mg/kg)	9000
Zinc (mg/kg)	10,000
Iron (mg/kg)	3,700
Fluorine (mg/kg)	1,000
Vitamin A (IU/kg)	1,000,000
Vitamin D (IU/kg)	150,000
Vitamin E (IU/kg)	1,000

Table. A.3 Ingredient and chemical composition of commercial pellets fed to calves

Item	Composition (%)
Ingredient (% DM)	
Wheat shorts	54.9
Ground barley	33.1
Canola meal	5.5
Vegetable oil	2.0
Coarse calcium	1.5
Ground wheat	1.1
Molasses Salt	1.0
Xtra Bond	0.2
FR Beef micro PRX	0.2
F.R.S.	0.049
Rumensin 200	0.033
Chemical Composition (%DM)	
Dry matter	88.4
Crude protein	15.7
Neutral detergent fiber	10.1
Total digestible nutrients	77.8
Calcium	0.83
Phosphorus	0.67
Digestible energy (Mcal kg^{-1})	3.58

DE = Digestible energy (calculated using Penn State equation based on ADF) (Adams 1995)

Table A.4 Average composition and analysis of finishing diet	
Diet composition (% DM basis)	
Barley silage	7.7
Barley grain	87.1
Supplement	5.2
Supplement composition (% DM basis)	
Canola meal	56.1
Limestone	20.8
Rumensin premix[z]	7.3
Trace mineral salt[y]	7.1
LS 106[x]	8.7
Chemical composition (DM basis)	
Crude protein	12.8
ADF	9.18
NDF	21.9
Calcium	0.54
Phosphorus	0.36

[z]Rumensin premix contains 200g kg^{-1} monensin sodium

[y]Trace mineral salt: 95% sodium chloride, 12 000 ppm zinc, 10 000 ppm manganese, 4000 ppm copper, 400 ppm iodine, 60 ppm cobalt, 30 ppm added selenium

[x]LS 106: 440 500 IU vitamin A, and 88 000 IU vitamin D_3 kg^{-1}

8.2 Appendix B

Table B.1 Prices of different commodities used during backgrounding trial in two years

Item	2007-08	2008-09
Hay ($/kg)	0.079	0.085
Supplement ($/kg)	0.29	0.29
Mineral and salt ($/kg)	1.27	1.25
Pre-seed herbicide ($/L)	11.92	10.3
Barley seed ($/kg)	0.24	0.24
Millet seed ($/kg)	1.54	1.68
Post-seed herbicide ($/L)	7.5	14.5
Fertilizer (Actual N)28-0-0 ($/kg)	0.365	0.795

Table B.2 Prices of different commodities used during finishing trial in two years

Item	2007-08	2008-09
Barley ($/kg)	0.225	0.160
Supplement ($/kg)	0.384	0.448
Oat ($/kg)	0.196	0.172
Canola meal ($/kg)	0.288	0.329
Hay ($/kg)	0.066	0.098